Climate Change Adaptation Research

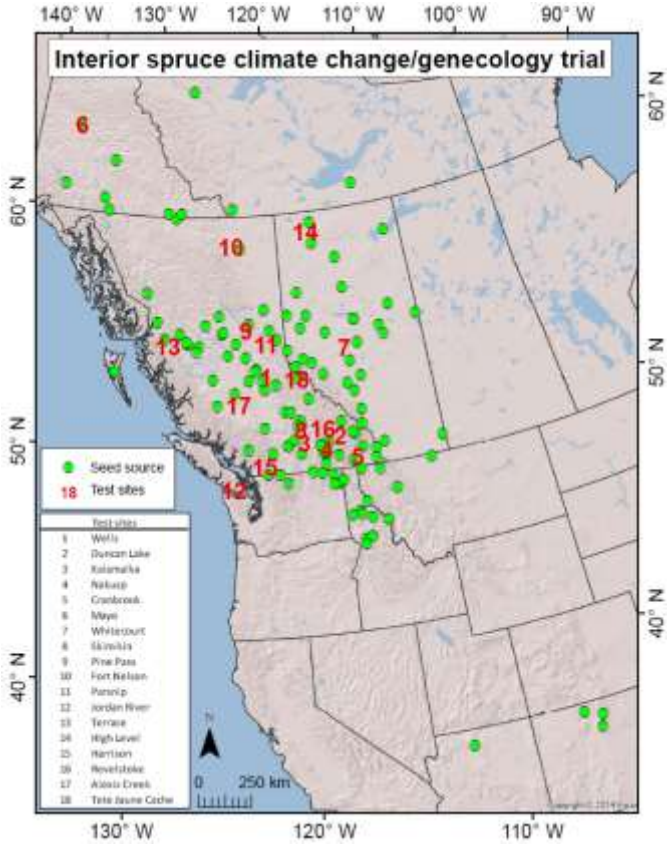
2023 highlights

1. Sx genecology/CC field trial maintenance
2. Assisted Migration Adaptation Trial (AMAT)
3. Climate Based Seed Transfer (CBST)
4. Multispectral imaging in prov trials (published)
5. Optimization and validation of URFs (published)
6. Improving species distribution models (published)
7. Climate sensitive mortality function (in press)
8. CC impacts to forest productivity (in prep)
9. Seed Trek 2.0 (in press)
10. Assisted range expansion (submitted)
11. Local adaptation to forest pests (in prep)
12. CBST evaluation (in prep)
13. Extension

Climate Change Adaptation Research

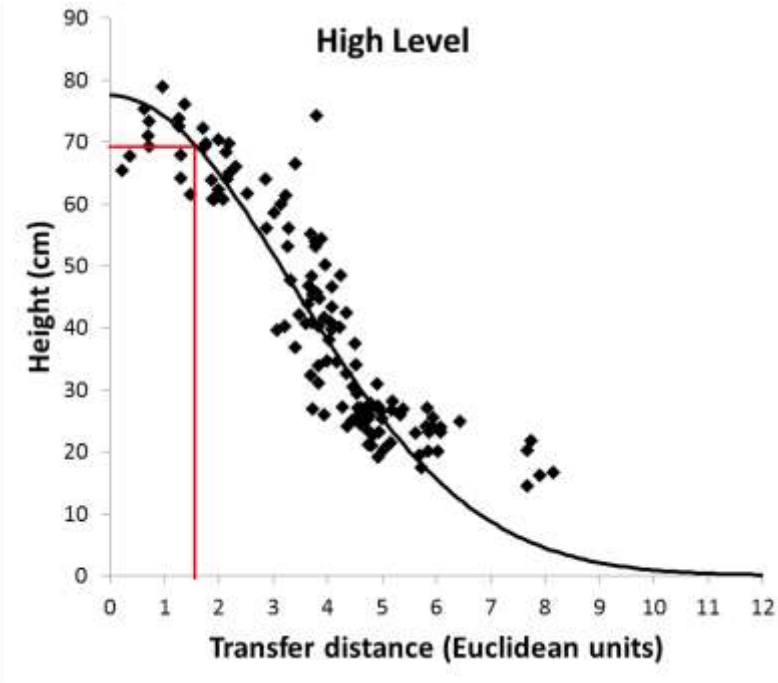
2023 highlights

1. Sx genecology/CC field trial



- Established 2005
- 127 pops at 17 test sites

Seedlot transferability → CBST



Climate Change Adaptation Research

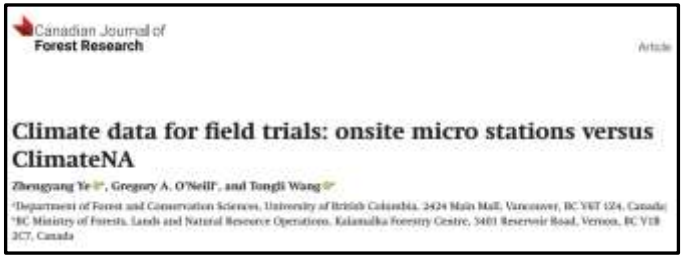
2023 highlights

1. Sx genecology/CC field trial

- OK to merge A and B ST systems

- Safe seed transfer distances for Sx
- Distances shorter in north interior

- Assisted migration can help mitigate CC impacts on productivity



- ClimateBC data is superior to on-site stations.

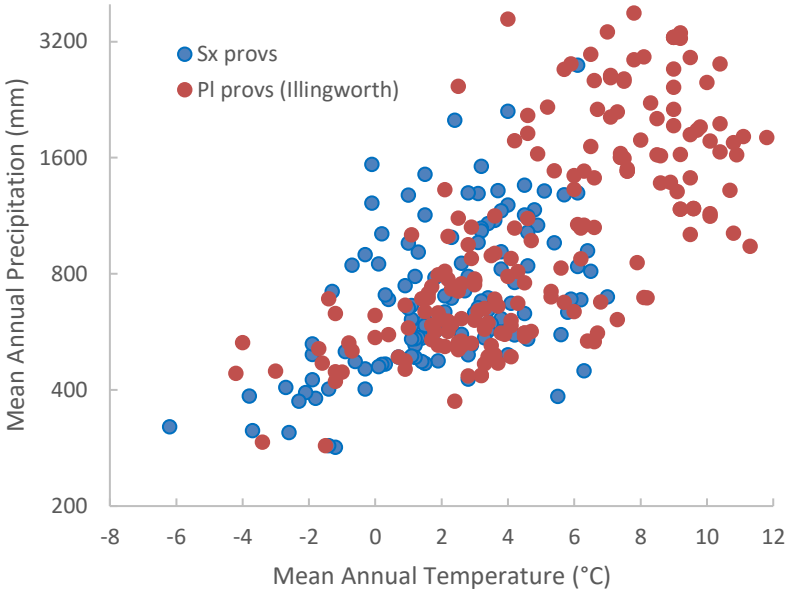
- Multi-spectral traits obtained using a drone may be superior to conventional traits in assessing adaptation

- Spatial validation can help identify the best models

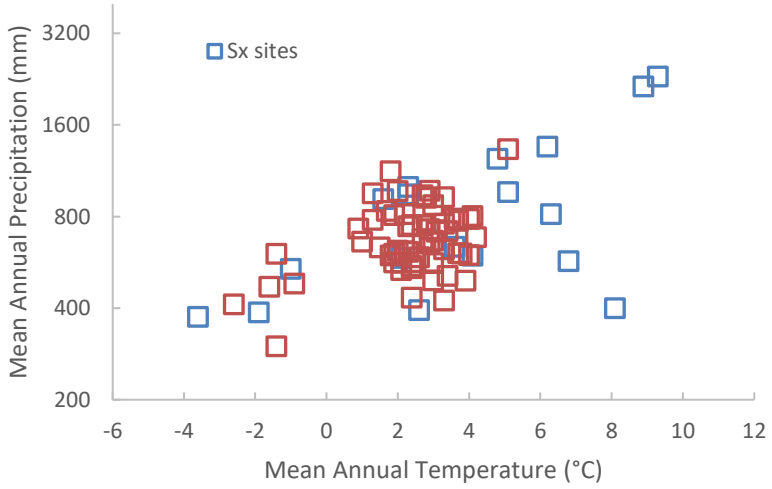
Climate Change Adaptation Research

2023 highlights

Provs



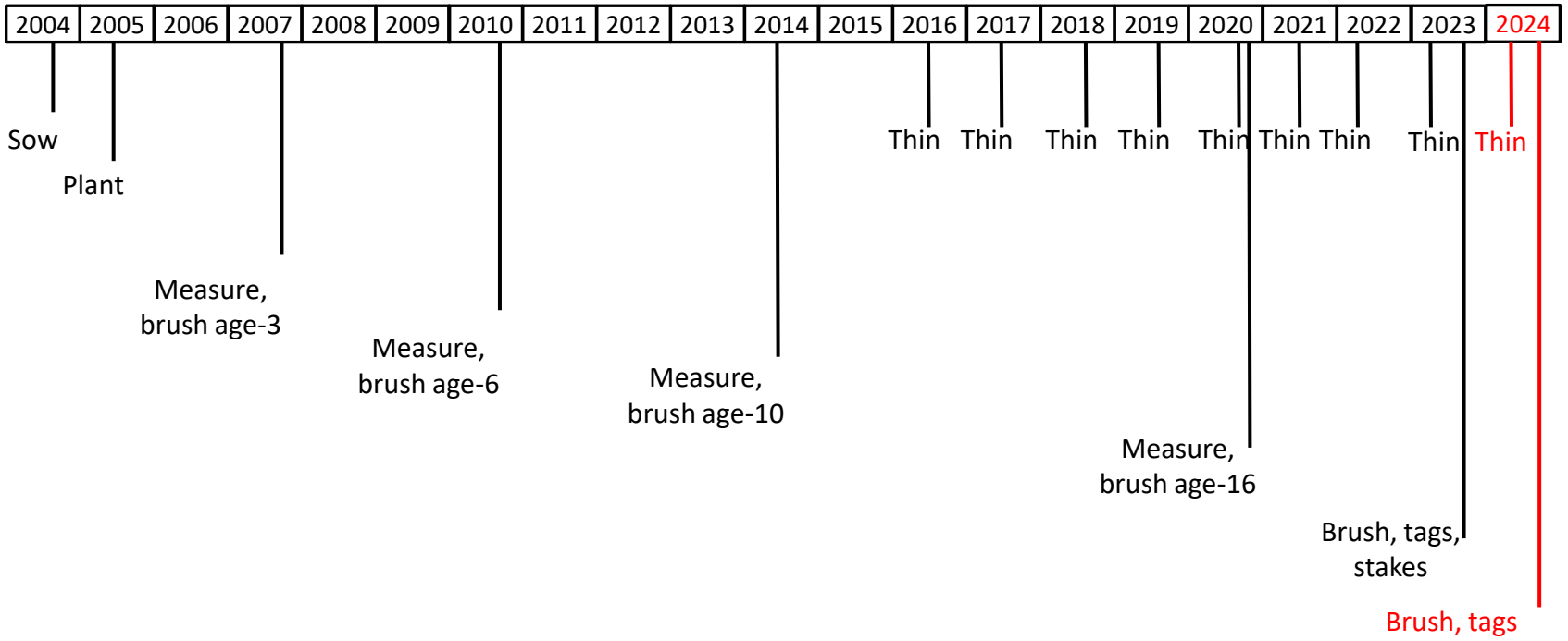
Sites



Climate Change Adaptation Research

2023 highlights

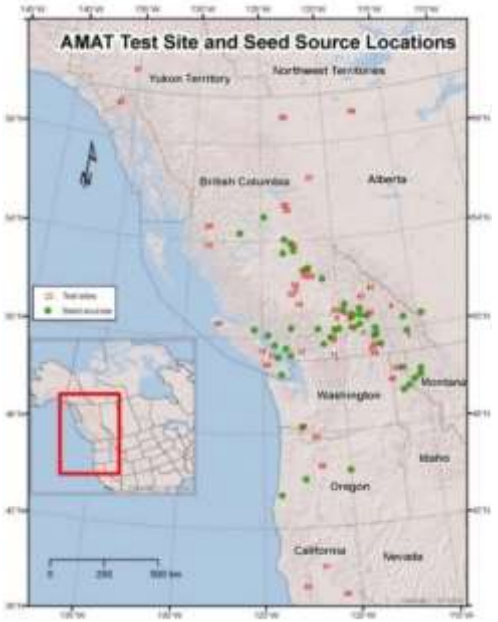
1. Sx genecology/CC field trial



2. Assisted Migration Adaptation Trial (AMAT)

- Established 2009-12
- 48 test sites
- 15 species, 47 seedlots (mostly Class A)

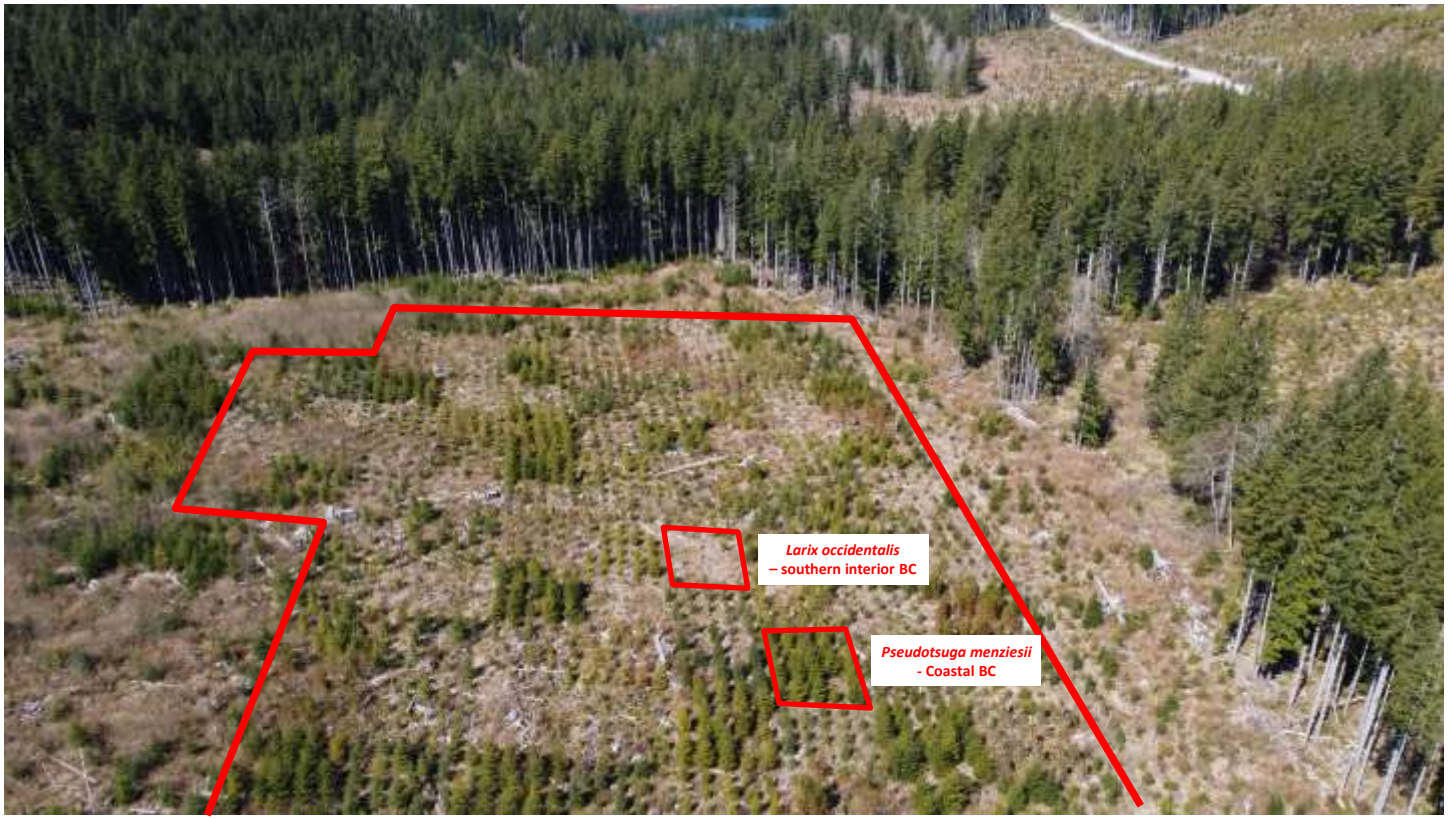
Photo: Ward Strong



Map: Amy Vallarino

- Seedlot transferability → CBST
- Calibrating CCISS

2. Assisted Migration Adaptation Trial (AMAT)



Nitinat AMAT, Vancouver Island, BC

2. Assisted Migration Adaptation Trial (AMAT)

Photo: Sam Grubinger

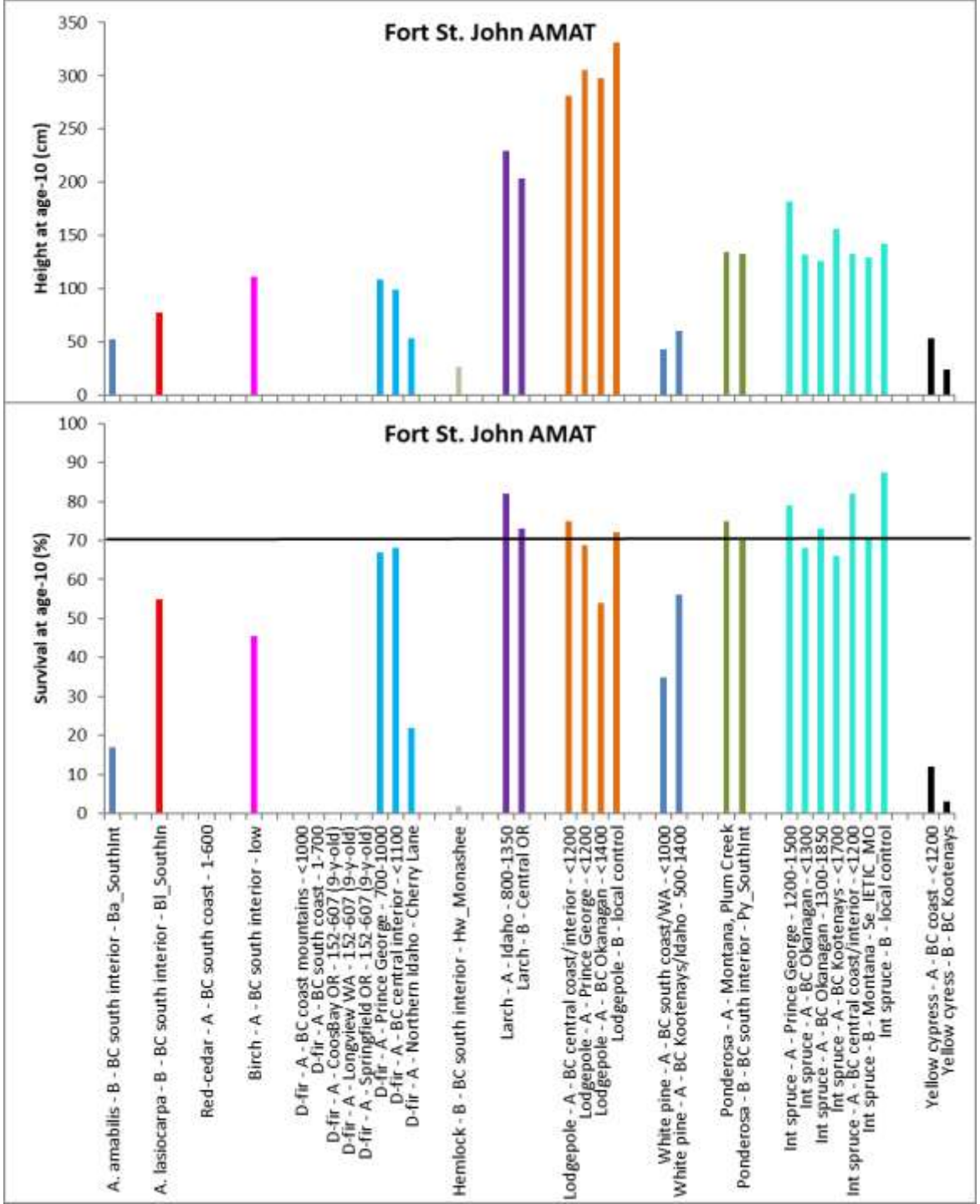
Kalamalka AMAT, Vancouver Island, BC

Climate Change Adaptation Research

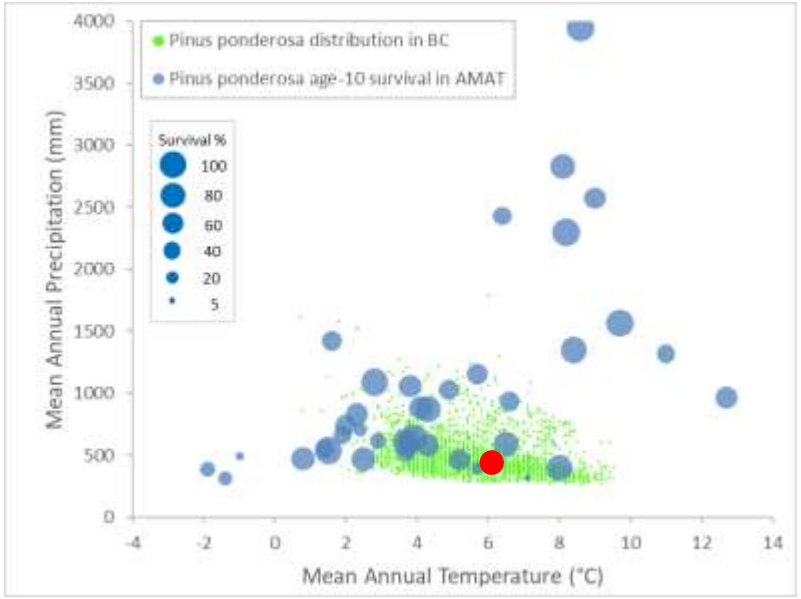
2023 highlights

2. Assisted Migration Adaptation Trial (AMAT)

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Project design	X																			
Proposal review		X																		
Seed procurement		X																		
Locate sites/grow seedlings - series 1			X																	
Locate sites/grow seedlings - series 2				X																
Locate sites/grow seedlings - series 3					X															
Locate sites/grow seedlings - series 4						X														
Plant - series 1				X																
Plant - series 2					X															
Plant - series 3						X														
Plant - series 4							X													
Weather station\site maintenance - series 1					X	X	X	X	X	X		X		X		X		X		X
Weather station\site maintenance - series 2						X	X	X	X	X	X		X		X		X		X	
Weather station\site maintenance - series 3							X	X	X	X	X	X		X		X		X		X
Weather station\site maintenance - series 4								X	X	X	X	X	X		X		X		X	
Assess - series 1								X					X					X		
Assess - series 2									X					X					X	
Assess - series 3										X					X					X
Assess - series 4											X					X				
Extension				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X


Fort St. John AMAT
Height at age-10 (cm)
0
50
100
150
200
250
300
350
Fort St. John AMAT
Survival at age-10 (%)
0
10
20
30
40
50
60
70
80
90
100
A. amabilis - B - BC south interior - Ba_SouthInt
A. lasiocarpa - B - BC south interior - Bl_SouthIn
Red-cedar - A - BC south coast - 1-600
Birch - A - BC south interior - low
D-fir - A - BC coast mountains - <1000
D-fir - A - BC south coast - 1-700
D-fir - A - CoosBay OR - 152-607 (9-y-old)
D-fir - A - Longview WA - 152-607 (9-y-old)
D-fir - A - Springfield OR - 152-607 (9-y-old)
D-fir - A - Prince George - 700-1000
D-fir - A - BC central interior - <1100
D-fir - A - Northern Idaho - Cherry Lane
Hemlock - B - BC south interior - Hw_Monashee
Larch - A - Idaho - 800-1350
Larch - B - Central OR
Lodgepole - A - BC central coast/interior - <1200
Lodgepole - A - Prince George - <1200
Lodgepole - A - BC Okanagan - <1400
Lodgepole - B - local control
White pine - A - BC south coast/WA - <1000
White pine - A - BC Kootenays/Idaho - 500-1400
Ponderosa - A - Montana, Plum Creek
Ponderosa - B - BC south interior - Py_SouthInt
Int spruce - A - Prince George - 1200-1500
Int spruce - A - BC Okanagan - <1300
Int spruce - A - BC Okanagan - 1300-1850
Int spruce - A - BC Kootenays - <1700
Int spruce - A - BC central coast/interior - <1200
Int spruce - B - Montana - Se_IETIC_MO
Int spruce - B - local control
Yellow cypress - A - BC coast - <1200
Yellow cypress - B - BC Kootenays

2. Assisted Migration Adaptation Trial (AMAT)



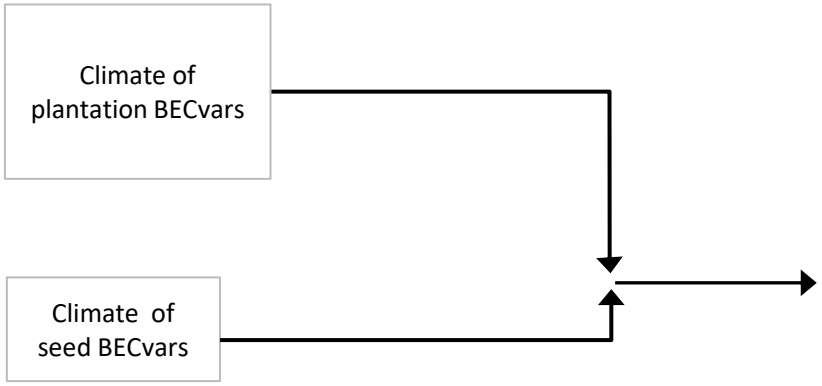
Range map: Little

2. Assisted Migration Adaptation Trial (AMAT)

Do not go to bank with age-10 results

- 10 years → insufficient extreme climate events
- Need to consider all sites simultaneously
- Cautious support for AM of species and populations.

3. CBST



Plantation \ Seed source	BAFAun	BGxh1	BGxw2	BWBSdk	BWBSmk	BWBSmw	BWBSvk	BWBSwk1	BWBSwk2
BAFAun	0.00	9.23	6.20	2.69	3.69	3.71	3.00	3.29	2.90
BGxh1	9.23	0.00	3.17	7.24	7.46	6.20	7.58	6.29	6.79
BGxw2	6.20	3.17	0.00	4.16	4.54	3.14	4.86	3.28	3.69
BWBSdk	2.69	7.24	4.16	0.00	1.63	1.41	2.52	1.77	0.73
BWBSmk	3.69	7.46	4.54	1.63	0.00	1.60	3.16	2.60	1.85
BWBSmw	3.71	6.20	3.14	1.41	1.60	0.00	2.67	1.30	0.99
BWBSvk	3.00	7.58	4.86	2.52	3.16	2.67	0.00	1.96	2.26
BWBSwk1	3.29	6.29	3.28	1.77	2.60	1.30	1.96	0.00	1.08
BWBSwk2	2.90	6.79	3.69	0.73	1.85	0.99	2.26	1.08	0.00

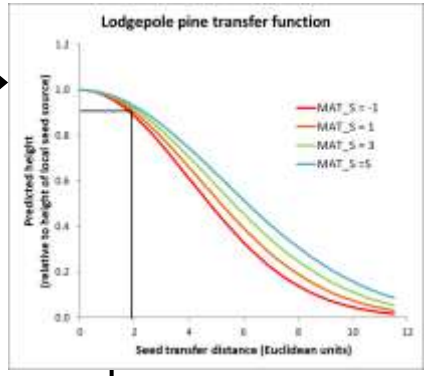
Climate distance matrix

Climate Change Adaptation Research

2023 highlights

3. CBST

Provenance data



Climate of plantation BECvars

Climate of seed BECvars

Plantation \ Seed source	BAFAun	BGxh1	BGxw2	BWBSdk	BWBSmk	BWBSmw	BWBSvk	BWBSwk1	BWBSwk2
BAFAun	0.00	9.23	6.20	2.69	3.69	3.71	3.00	3.29	2.90
BGxh1	9.23	0.00	3.17	7.24	7.46	6.20	7.58	6.29	6.79
BGxw2	6.20	3.17	0.00	4.16	4.54	3.14	4.86	3.28	3.69
BWBSdk	2.69	7.24	4.16	0.00	1.63	1.41	2.52	1.77	0.73
BWBSmk	3.69	7.46	4.54	1.63	0.00	1.60	3.16	2.60	1.85
BWBSmw	3.71	6.20	3.14	1.41	1.60	0.00	2.67	1.30	0.99
BWBSvk	3.00	7.58	4.86	2.52	3.16	2.67	0.00	1.96	2.26
BWBSwk1	3.29	6.29	3.28	1.77	2.60	1.30	1.96	0.00	1.08
BWBSwk2	2.90	6.79	3.69	0.73	1.85	0.99	2.26	1.08	0.00

Climate distance matrix

Plantation \ Seed source	BAFAun	BGxh1	BGxw2	BWBSdk	BWBSmk	BWBSmw	BWBSvk	BWBSwk1	BWBSwk2
BAFAun	1.00	0.02	0.17	0.72	0.53	0.53	0.66	0.61	0.68
BGxh1	0.36	1.00	0.89	0.54	0.52	0.63	0.51	0.63	0.58
BGxw2	0.50	0.83	1.00	0.73	0.69	0.84	0.65	0.82	0.78
BWBSdk	0.78	0.17	0.55	1.00	0.91	0.93	0.80	0.90	0.98
BWBSmk	0.60	0.12	0.46	0.90	1.00	0.91	0.69	0.78	0.88
BWBSmw	0.68	0.34	0.76	0.95	0.93	1.00	0.82	0.95	0.97
BWBSvk	0.81	0.27	0.58	0.86	0.80	0.85	1.00	0.92	0.89
BWBSwk1	0.77	0.38	0.77	0.93	0.85	0.96	0.91	1.00	0.97
BWBSwk2	0.77	0.25	0.66	0.98	0.90	0.97	0.86	0.96	1.00

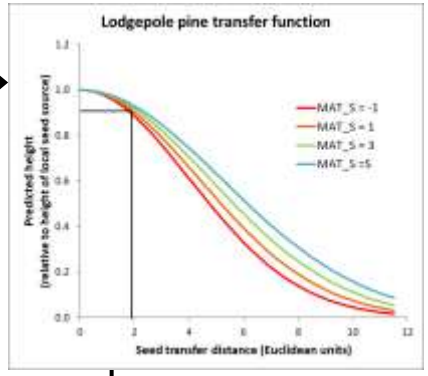
Relative height matrix
Genetic suitability

Climate Change Adaptation Research

2023 highlights

3. CBST

Provenance data



Climate of plantation BECvars + Climate migration distance

Climate of seed BECvars

Plantation \ Seed source	BAFAun	BGxh1	BGxw2	BWBSdk	BWBSmk	BWBSmw	BWBSvk	BWBSwk1	BWBSwk2
BAFAun	0.58	8.78	5.77	2.34	3.39	3.28	2.44	2.78	2.48
BGxh1	9.95	1.01	3.97	7.97	8.12	6.88	8.11	6.94	7.49
BGxw2	6.92	2.49	0.85	4.84	5.08	3.74	5.34	3.90	4.37
BWBSdk	3.25	6.65	3.62	0.71	1.58	0.92	2.39	1.48	0.66
BWBSmk	4.01	6.95	4.11	1.81	0.72	1.30	2.90	2.33	1.81
BWBSmw	4.19	5.75	2.80	1.99	2.05	0.68	2.66	1.35	1.49
BWBSvk	3.60	7.28	4.68	2.81	3.23	2.68	0.64	2.05	2.48
BWBSwk1	3.94	5.84	2.98	2.35	2.91	1.54	2.07	0.74	1.68
BWBSwk2	3.39	6.32	3.30	1.36	2.13	0.89	2.01	0.69	0.73

Climate distance matrix

Plantation \ Seed source	BAFAun	BGxh1	BGxw2	BWBSdk	BWBSmk	BWBSmw	BWBSvk	BWBSwk1	BWBSwk2
BAFAun	0.99	0.05	0.27	0.81	0.64	0.65	0.79	0.74	0.78
BGxh1	0.37	0.99	0.86	0.53	0.52	0.62	0.52	0.62	0.57
BGxw2	0.48	0.91	0.99	0.69	0.67	0.80	0.64	0.79	0.74
BWBSdk	0.73	0.27	0.68	0.99	0.93	0.98	0.84	0.94	0.99
BWBSmk	0.60	0.22	0.59	0.90	0.98	0.95	0.77	0.84	0.90
BWBSmw	0.66	0.45	0.83	0.91	0.90	0.99	0.84	0.96	0.95
BWBSvk	0.77	0.34	0.64	0.85	0.81	0.86	0.99	0.92	0.88
BWBSwk1	0.72	0.49	0.83	0.89	0.84	0.95	0.91	0.99	0.94
BWBSwk2	0.74	0.36	0.76	0.95	0.89	0.98	0.90	0.99	0.99

Relative height matrix
Genetic suitability

3. CBST

Considerations

- longer migration distance
- new measurement data (Sx)
- ClimateBC update
- BEC 13
- +/- drop PAS?
- +/- weight climate variables (temp > precip)?
- orphaned plantation BECvars

Conversations

- genetics community
- seed user/producer community.

4. Multi-spectral imaging in forest genetics trials

Objective

- What opportunities exist for multispectral imaging from drones to contribute to assessment of genetics field trials?

Funding 2020/21

- MoF $30,000
- NSERC $60,000

Team

- Sam Grubinger, Nicholas Coops, Greg O'Neill

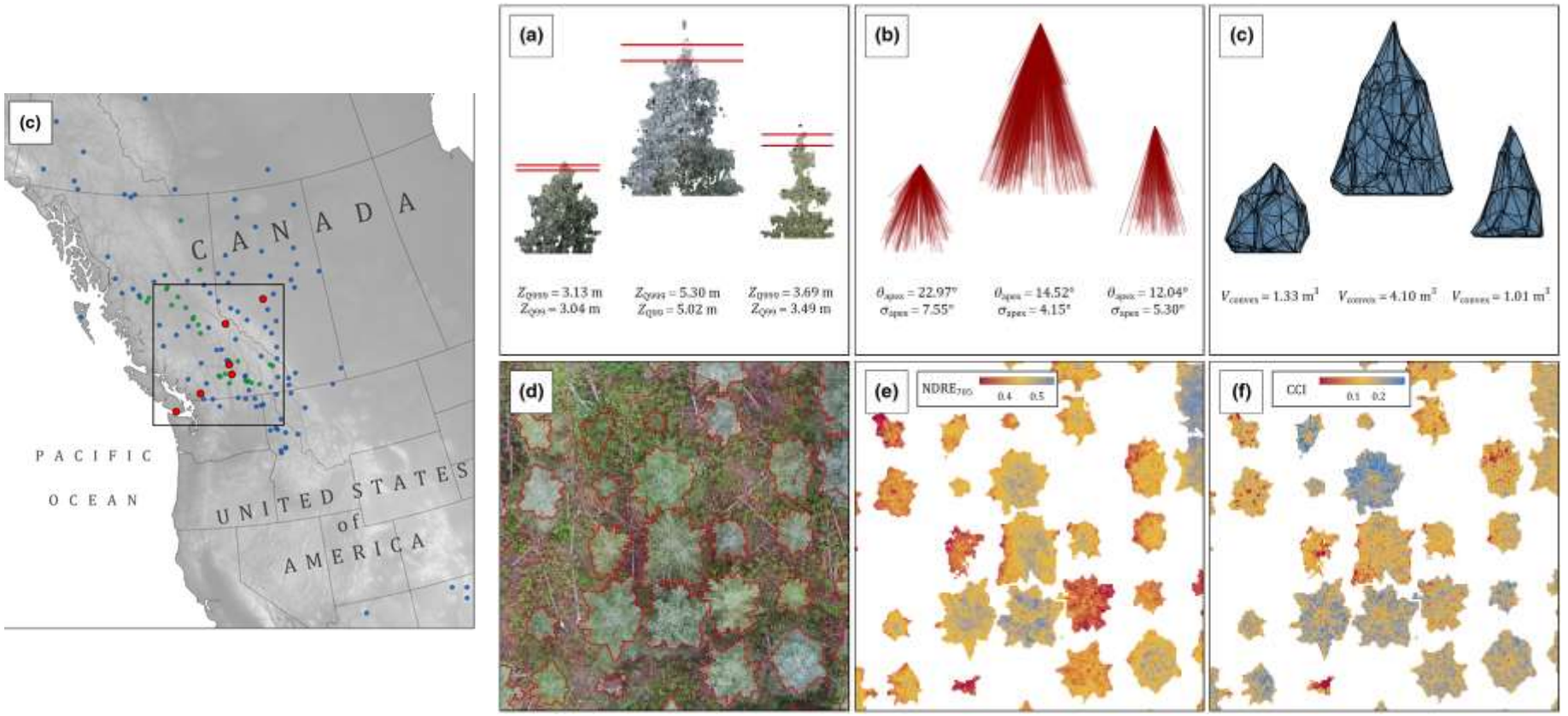
Deliverables

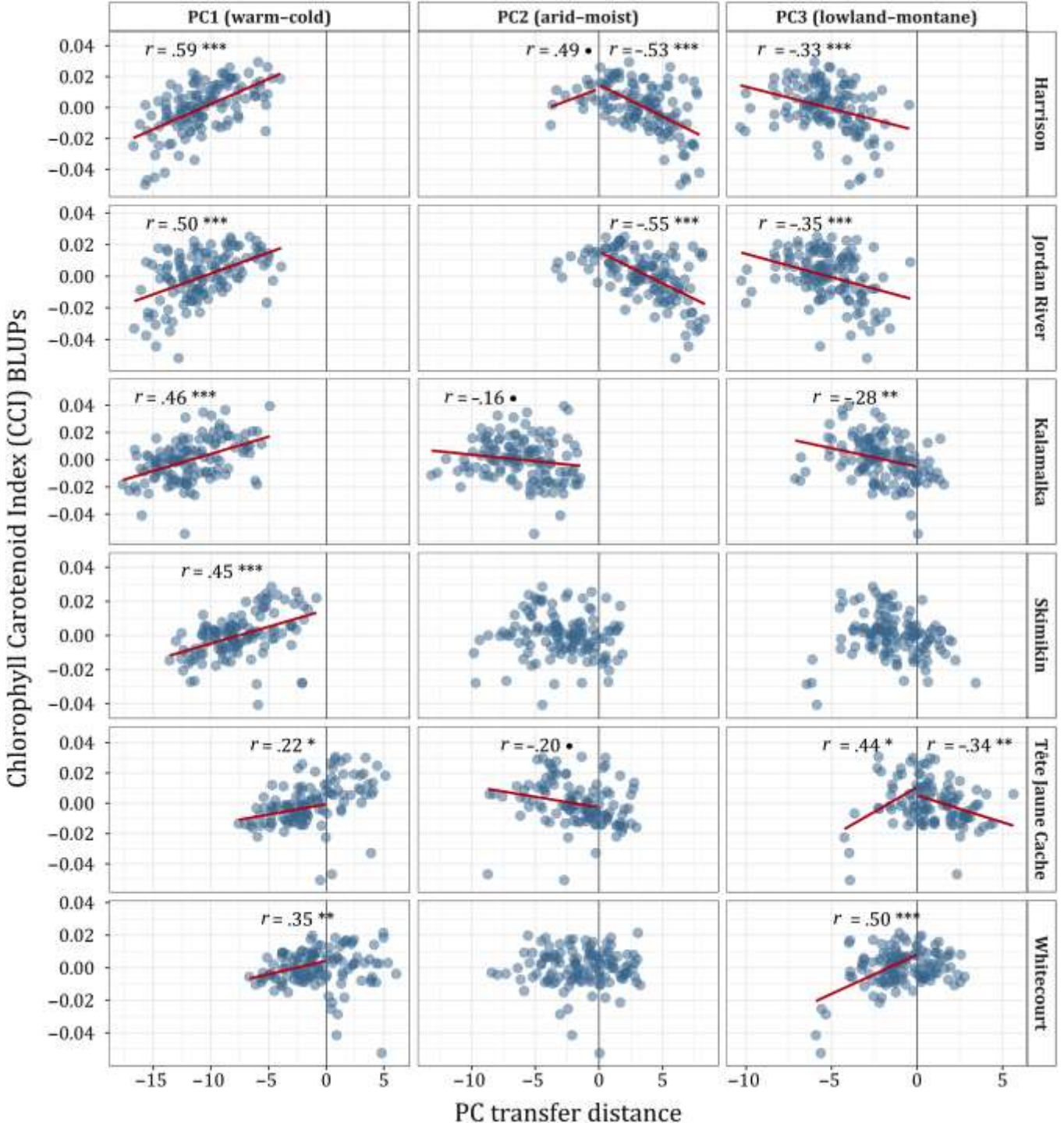
- Grubinger et al. 2023. *Picturing local adaptation: Spectral and structural traits from drone remote sensing.* GCB

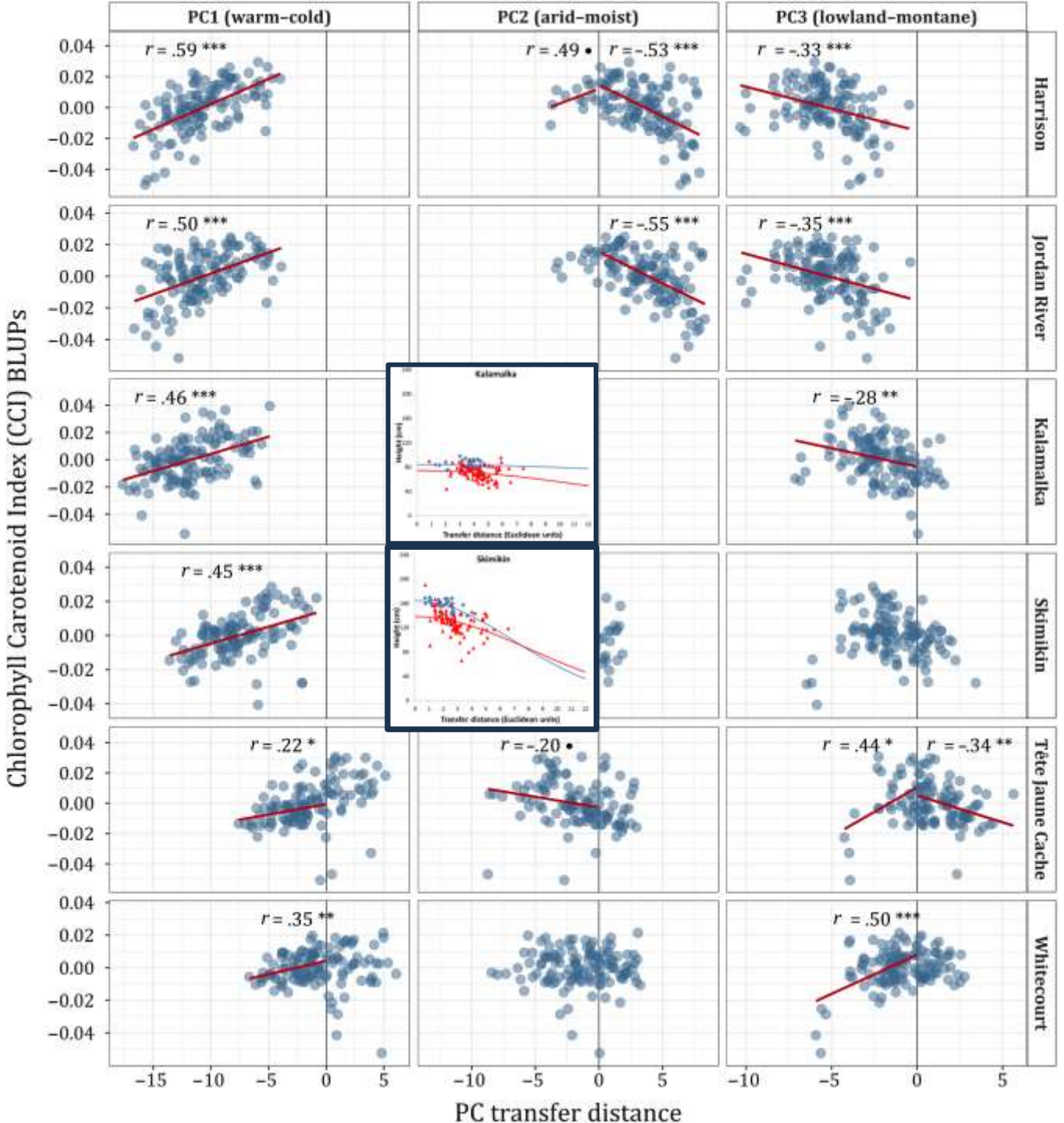
Extension

- Forest Phenotyping Working Group Seminar, Nanjing, China (Nov 2023)
- Western Forest Genetics Association, Vernon (July 2023)
- BC Tree Breeders' Meeting, Lake Cowichan (Nov 2022)
- Forest Remote Sensing workshop – ForSat, Berlin, Germany (Sept 2022)

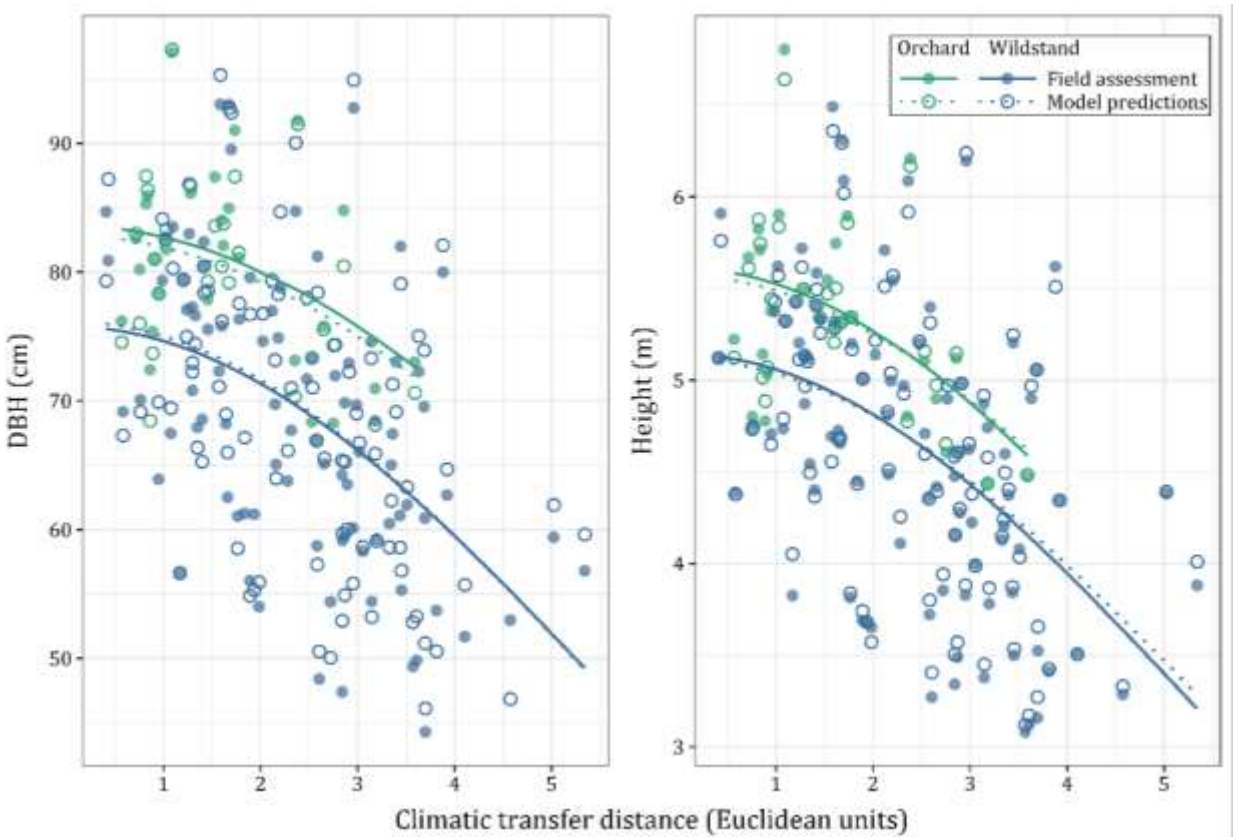
4. Multi-spectral imaging in forest genetics trials




PC1 (warm–cold)
PC2 (arid–moist)
PC3 (lowland–montane)
Harrison
Jordan River
Kalamalka
Skimikin
Tête Jaune Cache
Whitecourt
r = .59 ***
r = .49 •
r = −.53 ***
r = −.33 ***
r = .50 ***
r = −.55 ***
r = −.35 ***
r = .46 ***
r = −.16 •
r = −.28 **
r = .45 ***
r = .22 *
r = −.20 •
r = .44 *
r = −.34 **
r = .35 **
r = .50 ***
Chlorophyll Carotenoid Index (CCI) BLUPs
PC transfer distance
0.04
0.02
0.00
−0.02
−0.04
−15
−10
−5
0
5


PC1 (warm–cold)
PC2 (arid–moist)
PC3 (lowland–montane)
Harrison
Jordan River
Kalamalka
Skimikin
Tête Jaune Cache
Whitecourt
r = .59 ***
r = .49 •
r = -.53 ***
r = -.33 ***
r = .50 ***
r = -.55 ***
r = -.35 ***
r = .46 ***
r = -.28 **
r = .45 ***
r = .22 *
r = -.20 •
r = .44 *
r = -.34 **
r = .35 **
r = .50 ***
Chlorophyll Carotenoid Index (CCI) BLUPs
PC transfer distance

4. Multi-spectral imaging in forest genetics trials



5. Optimization and validation of Universal Response Functions

Objective

- How to improve Universal Response Functions?

Funding

- 2020/21 – $25,000 (FCI)
- 2021/22 – $30,000, Wang (NSERC)
- 2022/23 – $30,000, Wang (NSERC)

Team

- Zhengyang (Lambert) Ye, Tongli Wang, Greg O'Neill

Deliverables

- Publication: "Optimization and validation of universal response functions for interior spruce" (FEM, 2023)

5. Optimization and validation of Universal Response Functions

$$Height = f(Clim_{site}, Clim_{seed}, Clim_{site} X\ Clim_{seed})$$

- Stand productivity – local seed
- Stand productivity – migrated seed within range
- Stand productivity – migrated seed outside of range

5. Optimization and validation of Universal Response Functions

Height = f($Clim_{site}$, $Clim_{seed}$, $Clim_{site}$X $Clim_{seed}$)

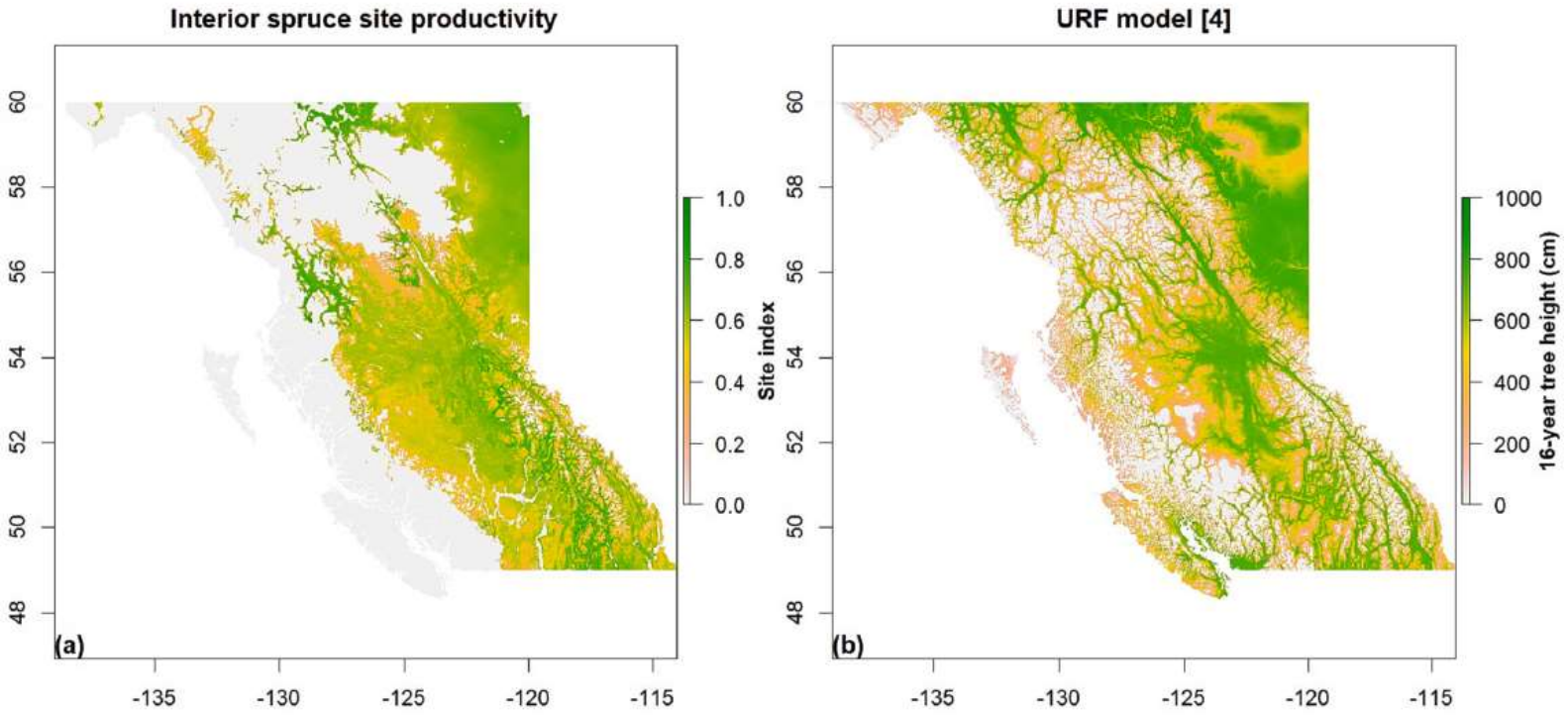
- Stand productivi… seed
- Stand produc… grated seed within range
- Stand producti… migrated seed outside of range

Present and future

5. Optimization and validation of Universal Response Functions

Height = f($Clim_{site}$, $Clim_{seed}$, $Clim_{site}$X $Clim_{seed}$)

- Stand productivity – local seed
- Stand productivity – future migrated seed within range
- Stand productivity – future migrated seed outside of range



6. Improving species distribution models

Objective/Questions

- How can species distribution models be improved?

Funding

- 2021/22 $30,000 (NSERC - Wang)
- 2022/23 – $30,000 (NSERC - Wang)

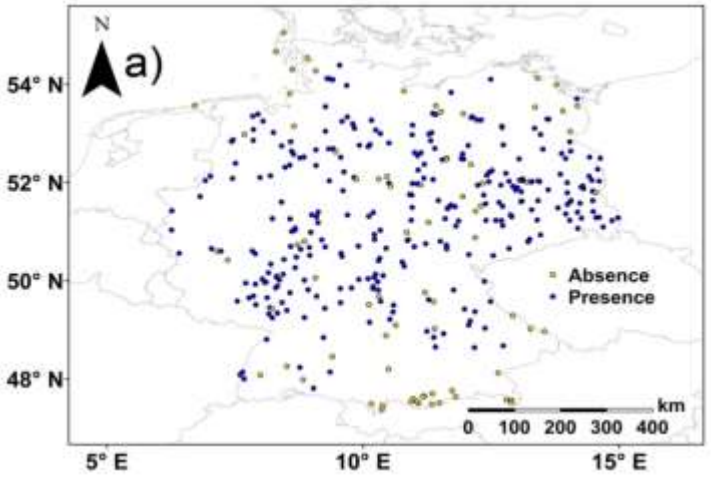
Team

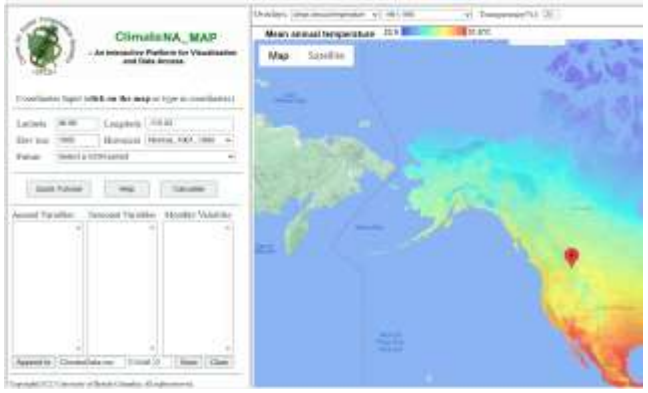
- Yueru Zhao, Greg O'Neill, Tongli Wang

Deliverables

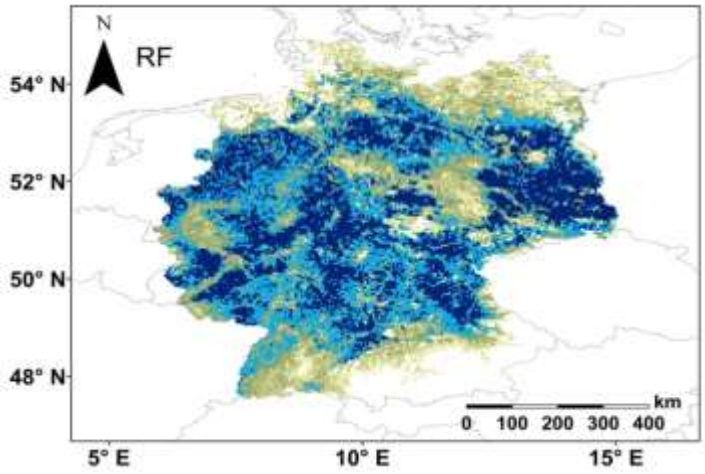
- Publication: "*Predicting fundamental climate niches of forest trees based on species occurrence data*" (Ecological Indicators, 2023)

6. Improving species distribution models





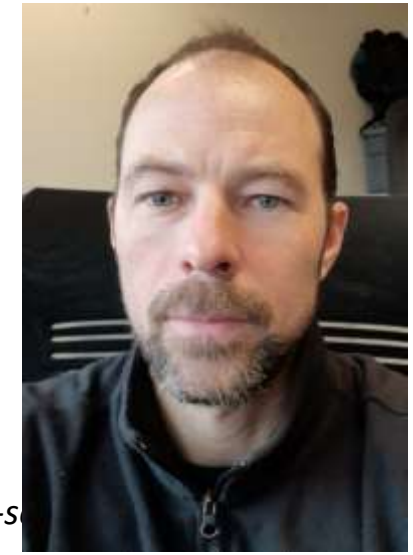
RF
MAXent
GAM



- Best model from (RF + MAXent)
- Optimum P/A ratio = 0.3 to 0.5
- Optimum suitability value = 0.3

7. Climate Sensitive Mortality Function

Objective
- Simulate climate-induced mortality in lodgepole pine stands and apply to TASS



Funding
- 2019/20 - Forest Enhancement Society ($76,000), FAIB ($25,000)
- 2020/21 - OCF Research Program (Timber Portfolio) ($51,000)
- 2021/22 - OCF Research Program (Timber Portfolio) ($51,000)
- 2022/23 - OCF Research Program (Timber Portfolio) ($51,000)

Team
- Derek Sattler, Kate Peterson, Tongli Wang, Greg O'Neill

Deliverables
- Technical Report "*A transfer function for survival and its use in developing climate-s projections of volume for lodgepole pine*" (in press)

Extension
- Western Mensurationists' Conference 2020 (Peterson)
- International Boreal Forest Research Association conference 2021 (Peterson)
- Canadian Wood Fibre Centre – Forest productivity and CC working group (March 2021) (Sattler)
- CFGA/WFGA Symposium 2021 (Peterson)

8. CC impacts to lodgepole pine productivity

Objective

- To assess the impacts of climate change on lodgepole pine productivity in BC using a climate sensitive G&Y model

Funding

- 2023/24 – NSERC Student Award ($36,000)

Team

- Kate Peterson, Derek Sattler, Tongli Wang, Greg O'Neill

Deliverables

- PhD thesis (2026)
- Publication (2026)

8. CC impacts to lodgepole pine productivity

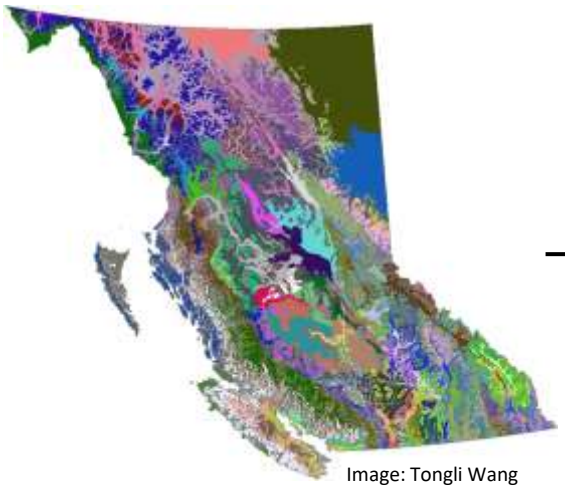


Image: Tongli Wang

Climate-sensitive TASS

Factors
SI
Planting density
RCP
Genetic diversity

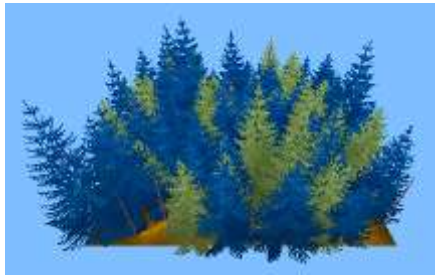


Image: Dave Simpson

9. CBST 101

Objective
- To write a document that introduces climate-based seed transfer to practitioners

Funding
- none

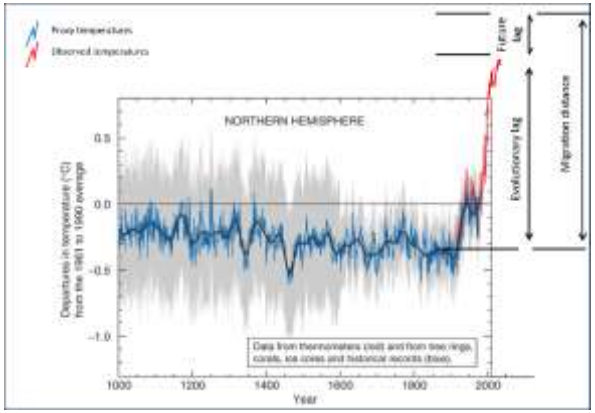
Team
- Greg O'Neill, Jon Degner

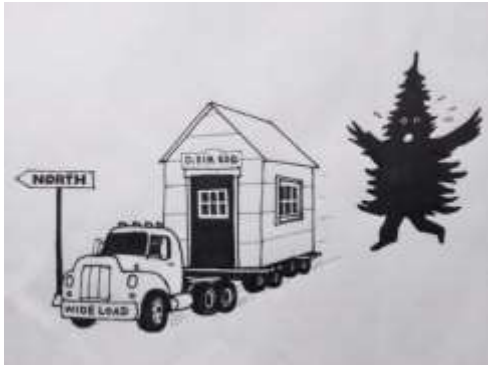
Deliverables
- Publication: "Seed Trek 2.0: The Next Generation of Seed Transfer Systems" (Tree Planters' Notes, Spring 2024)

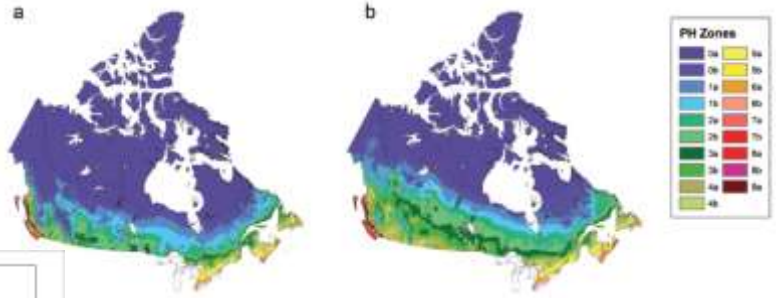
Climate Change Adaptation Research

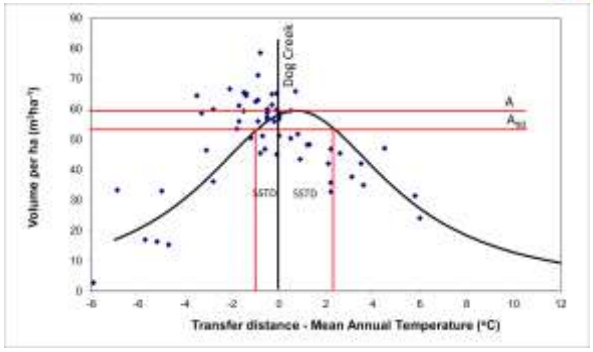
2023 highlights

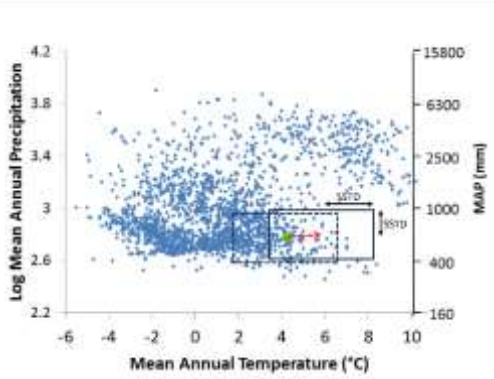
9. CBST 101











10. Assisted Range Expansion

Objective
- To assess the productivity of Lw, Py and Fd when planted outside of its current geographic range

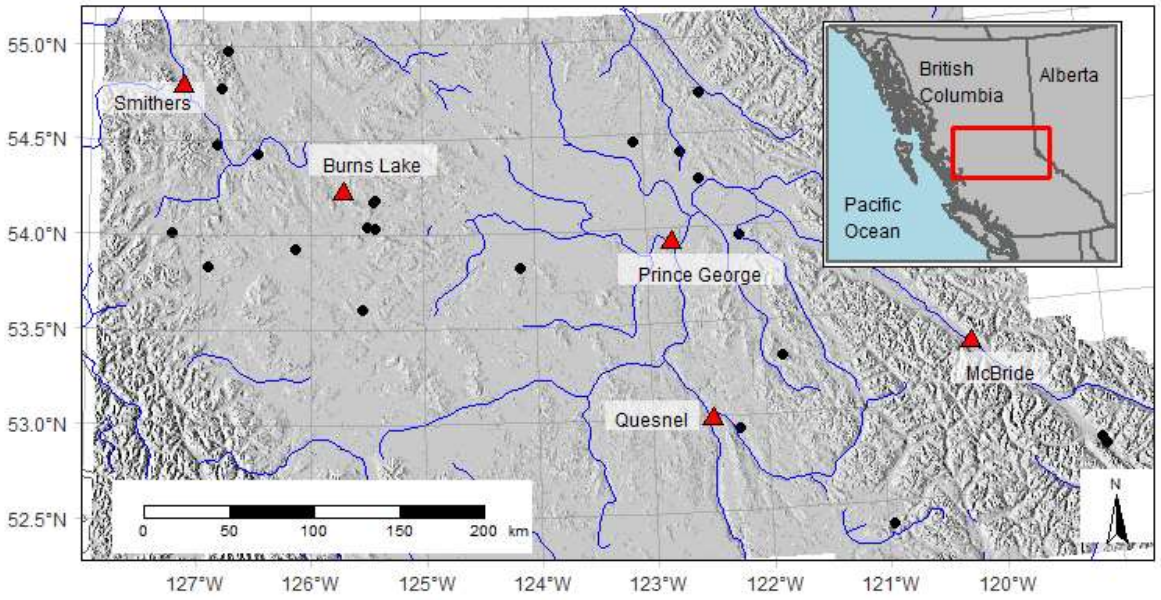
Funding 2022/23
- BC MoF Research Program - $35,000

Team
- Hardy Griesbauer, Will Mackenzie, Greg O'Neill

Deliverables
- Publication: "Experimental plantations of tree species outside their current geographic range informs assisted migration in central BC"

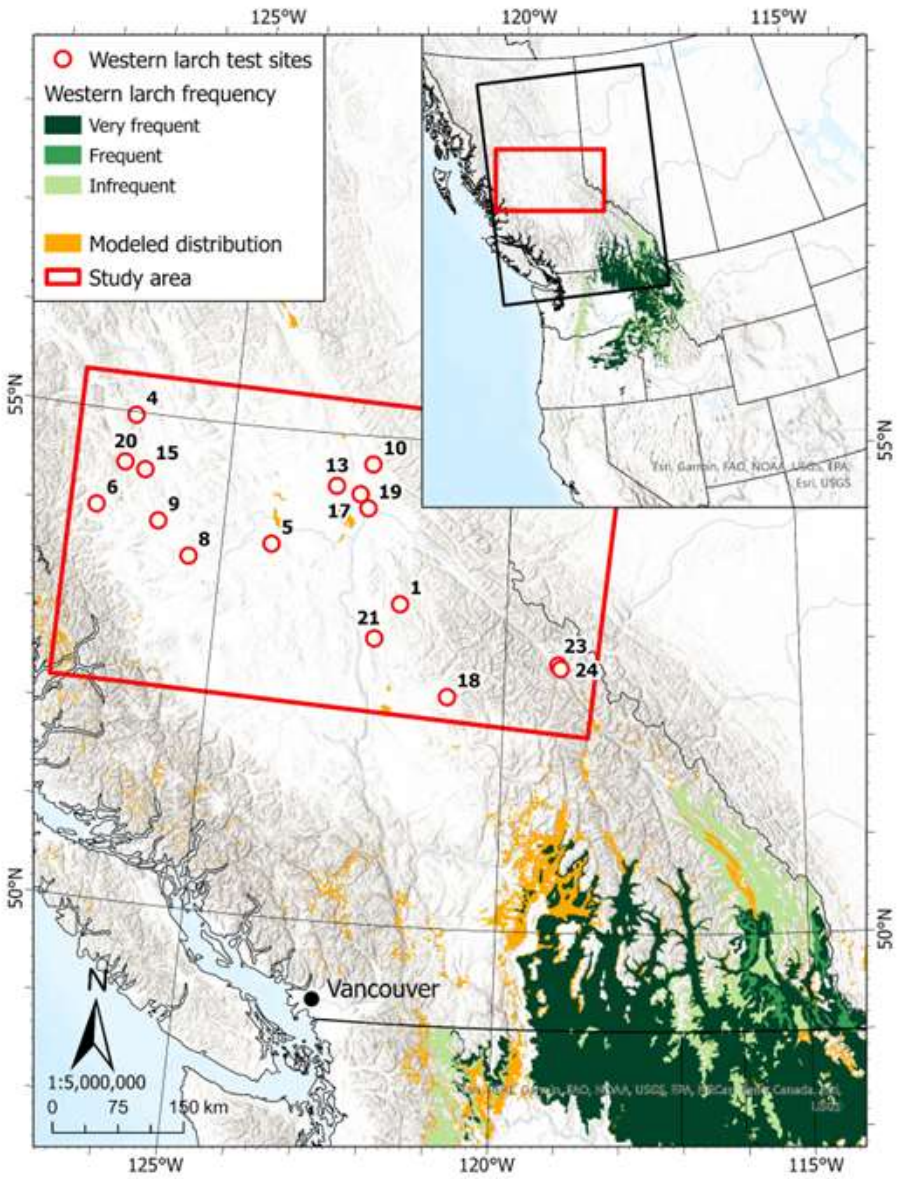
Extension
- Northern Silviculture Committee (Feb 2023)

10. Assisted Range Expansion



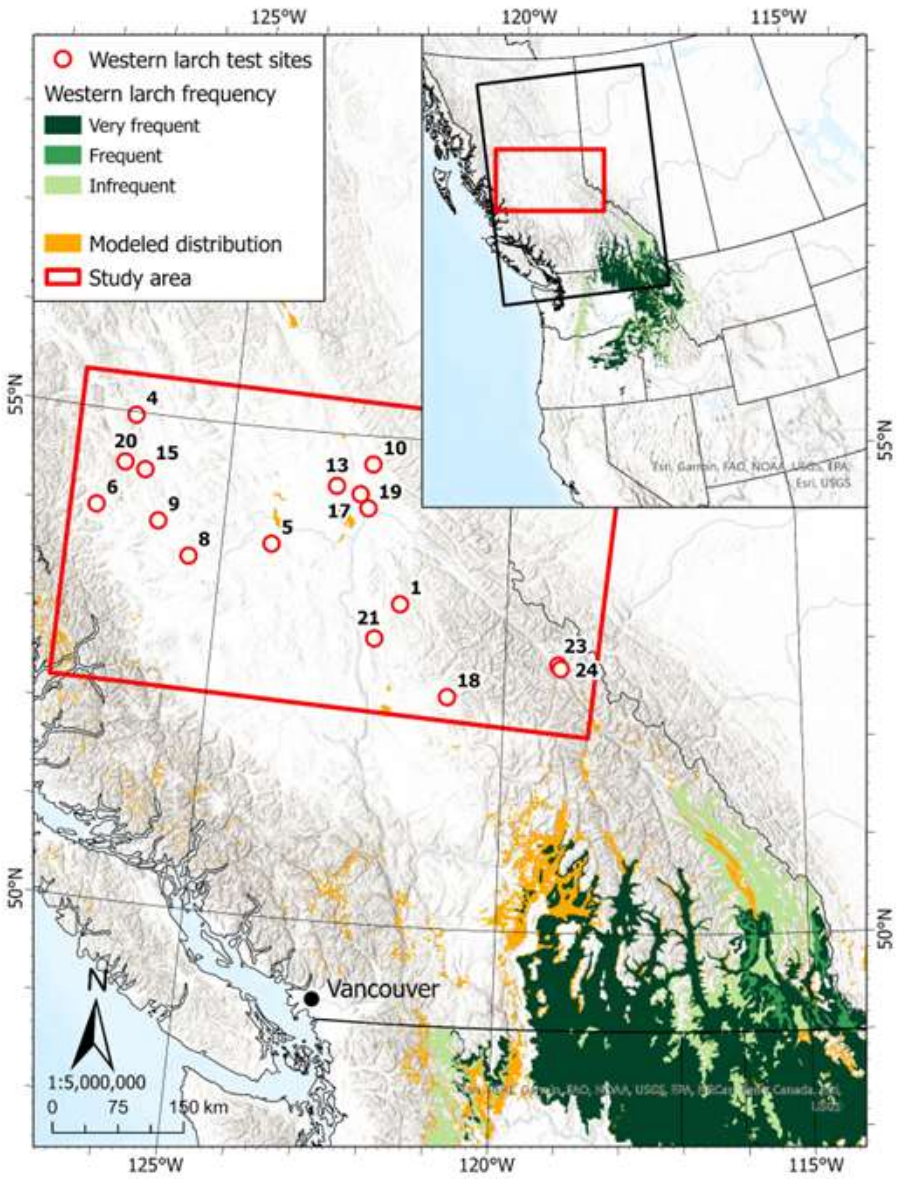
Climate Change Adaptation Research

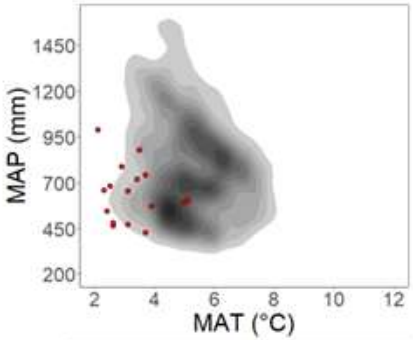
2023 highlights

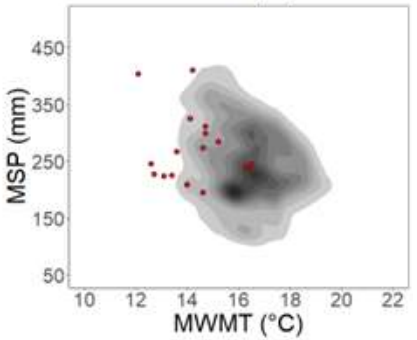


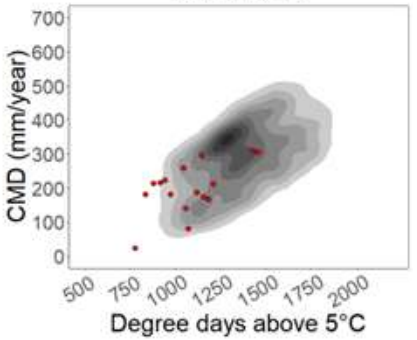
Climate Change Adaptation Research

2023 highlights

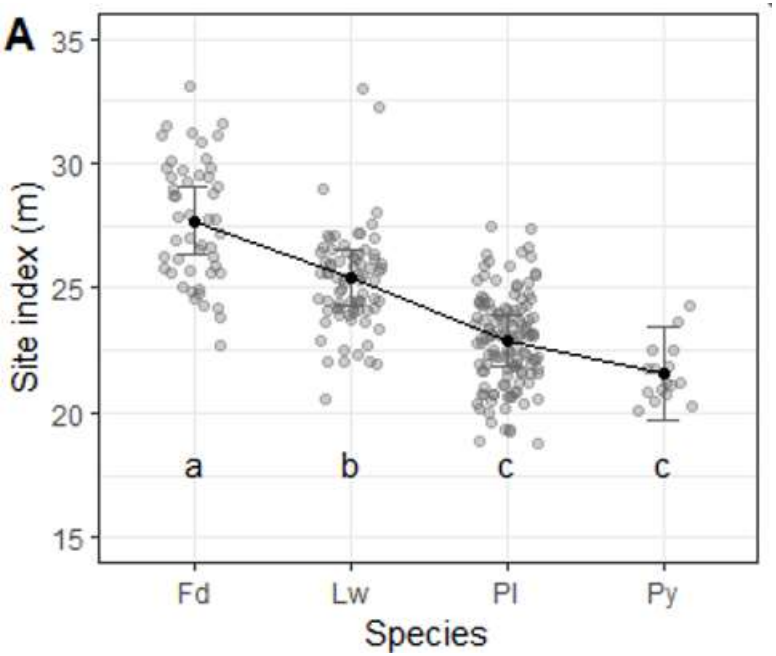








10. Assisted Range Expansion



11. Local adaptation of trees to forest pests

Objective/Questions

- Can pest damage be controlled with specific seed transfer constraints?

Funding

- 2021/22 – $45,000 (FCI)
- 2022/23 – $65,000 (FCI)

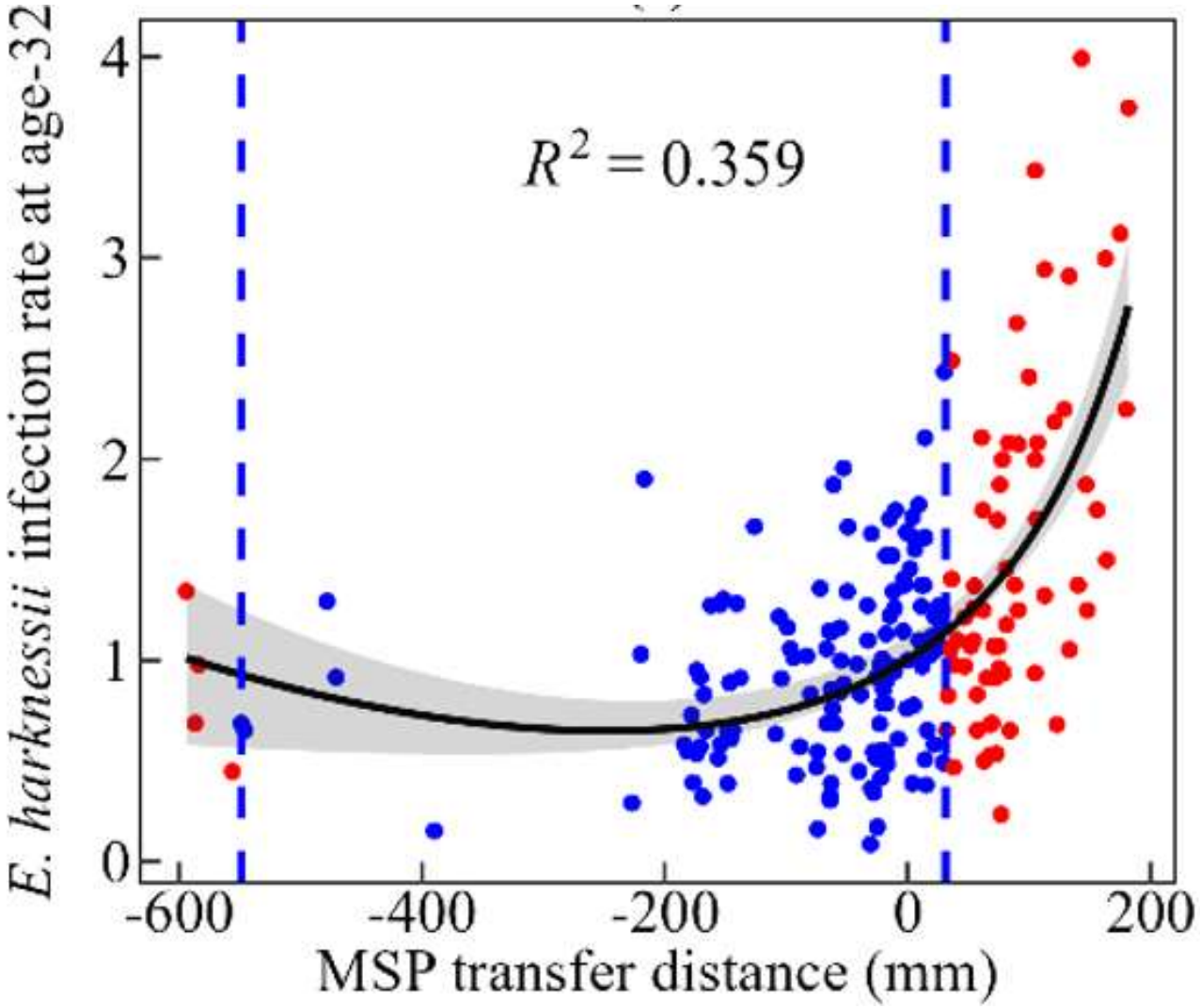
Team

- Dawei Luo, Greg O'Neill, Nick Ukrainetz, Deogratias Rweyongeza, Peter Ott, Tom Booker, Ian MacLachlan, Tongli Wang

Deliverables

- Publication: "*Better forest health through better seed transfer*" (in prep)

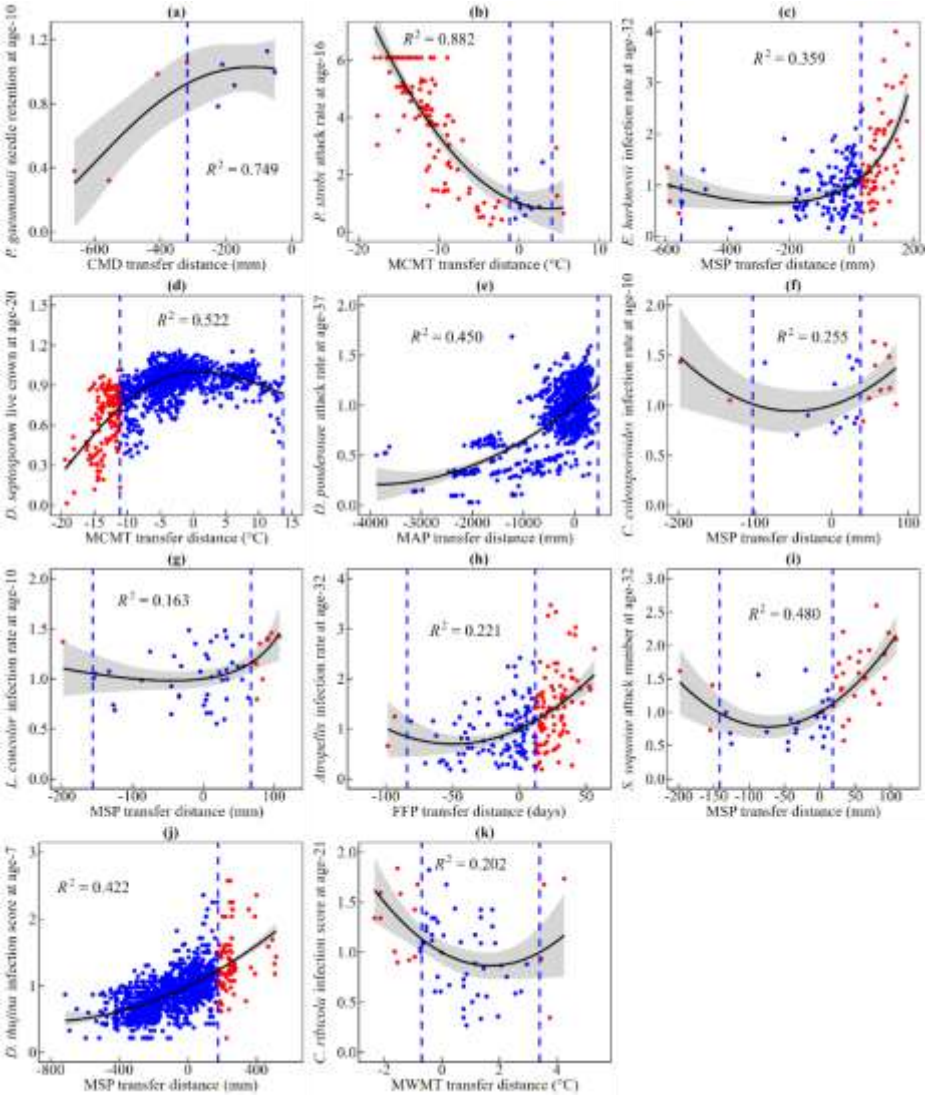
11. Local adaptation of trees to forest pests



Climate Change Adaptation Research

2023 highlights

11. Local adaptation of trees to forest pests



12. CBST evaluation

Objective/Questions

- Does CBST result in better adaptation and a wider deployment area?
- Does AM result in better adaptation?
- How does choice of genetic suitability threshold after adaptation and deployment area?

Funding

- 2021/22 – $45,000 (FCI)
- 2022/23 – $65,000 (FCI)

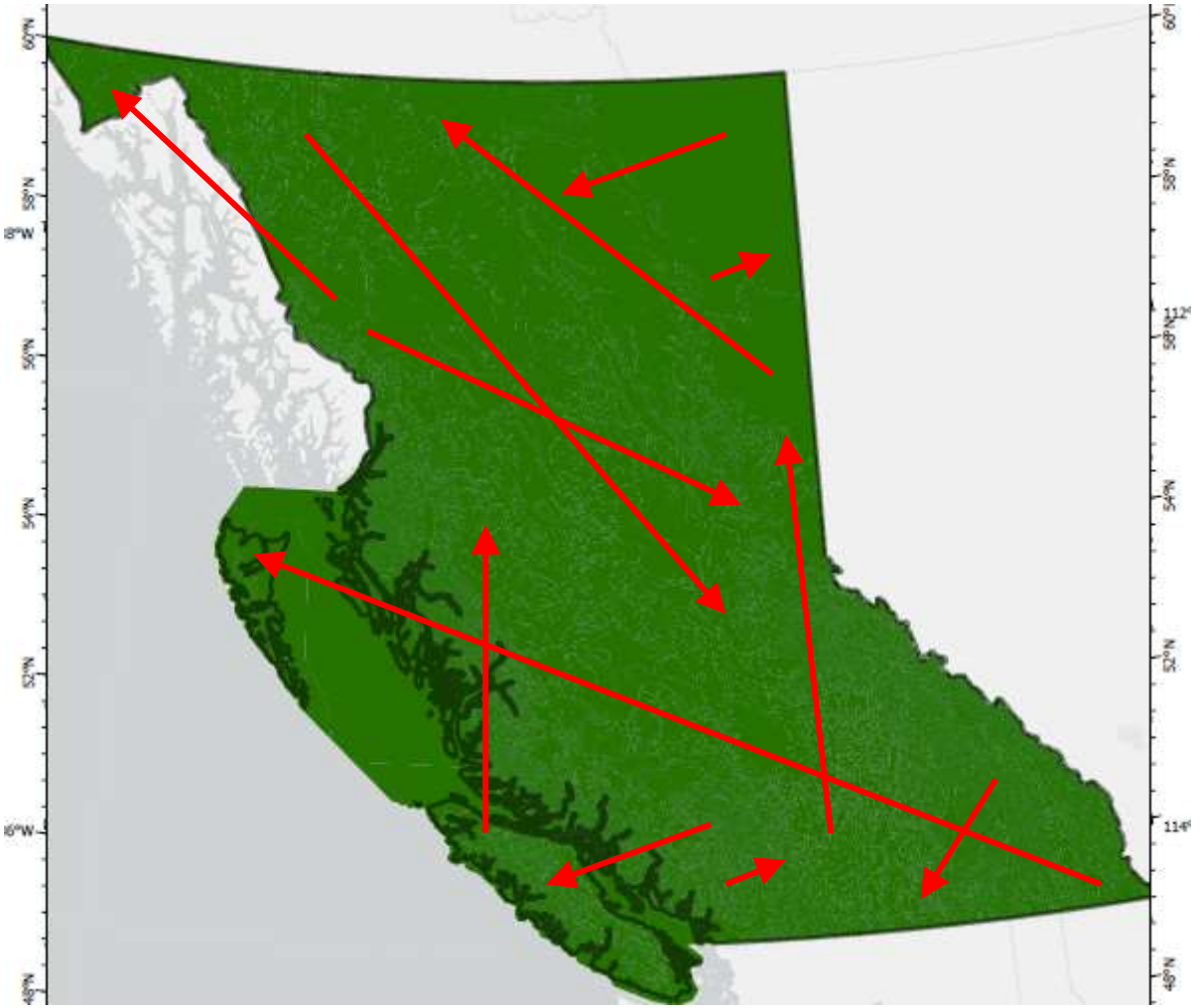
Team

- Dawei Luo, Greg O'Neill, Ian MacLachlan, Barb Thomas, Tongli Wang

Deliverables

- Publication: "Evaluating climate based seed transfer and assisted migration" (in prep)

12. CBST evaluation

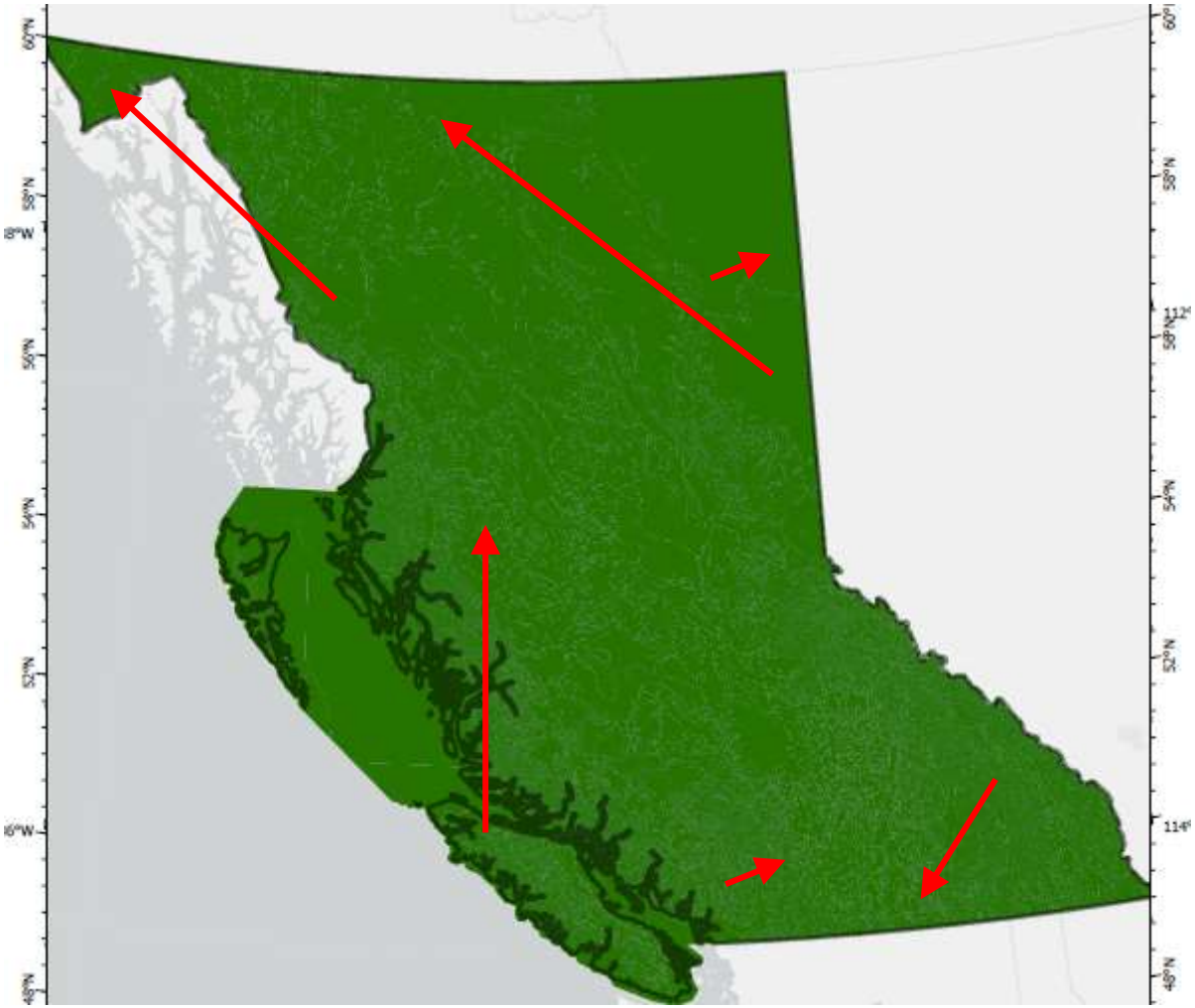


12. CBST evaluation

Sx and Pl

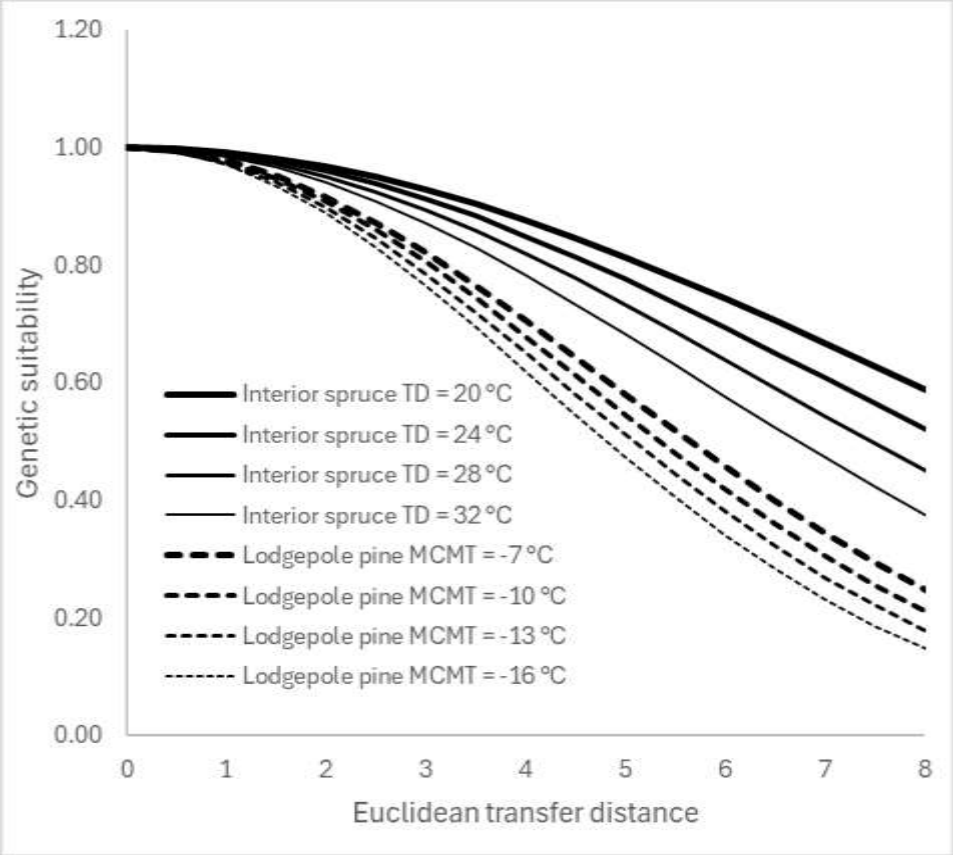
GBST
CBST
CBST with AM

GS 0.92 to 0.99

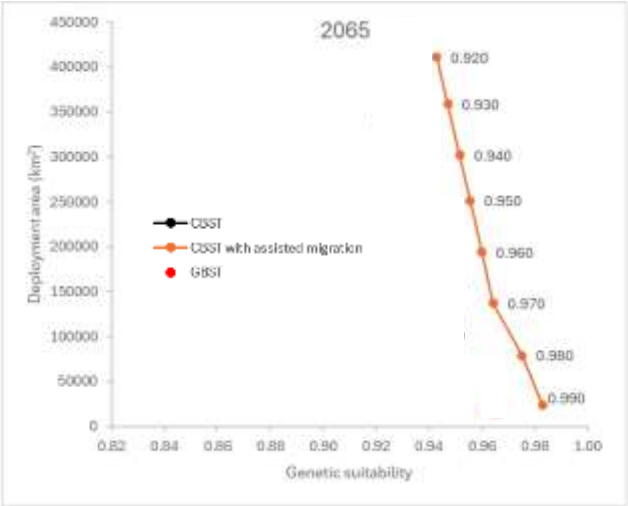


Calculated:
GS
Deployment area

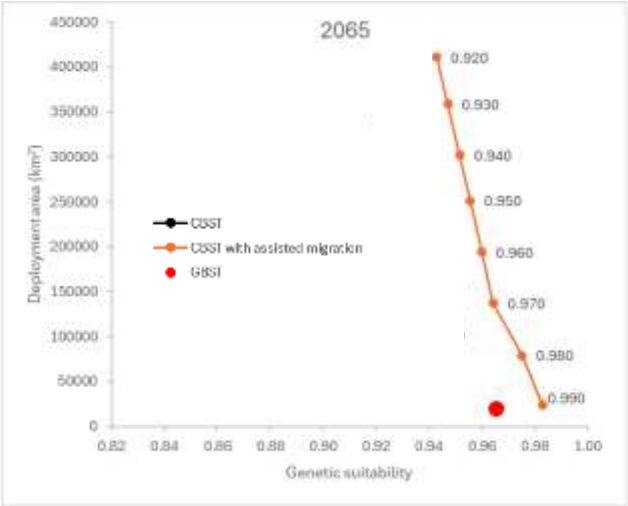
12. CBST evaluation



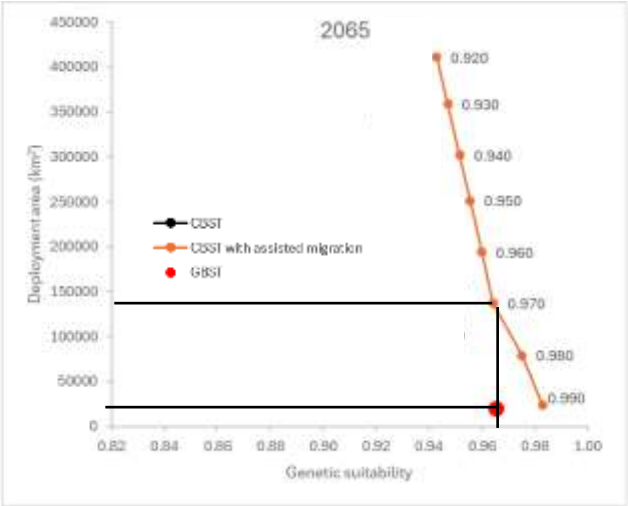
12. CBST evaluation



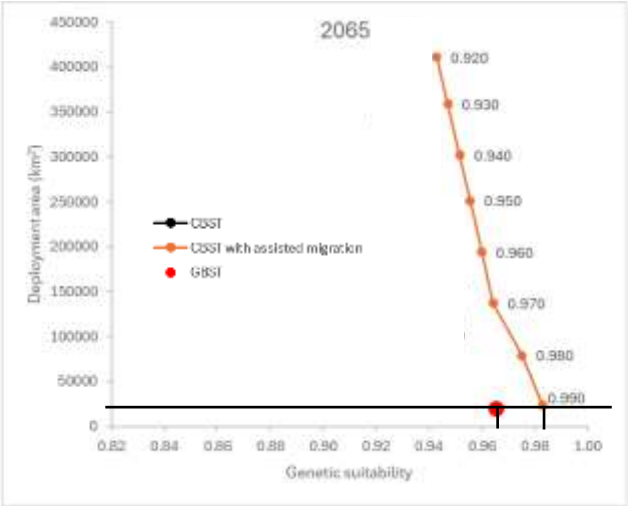
12. CBST evaluation



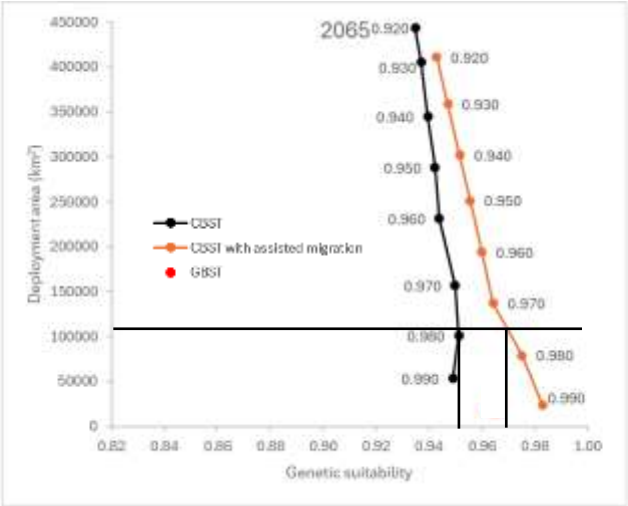
12. CBST evaluation



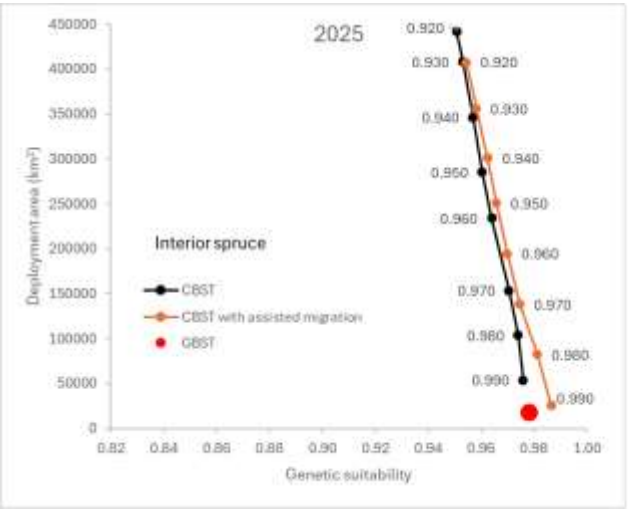
12. CBST evaluation

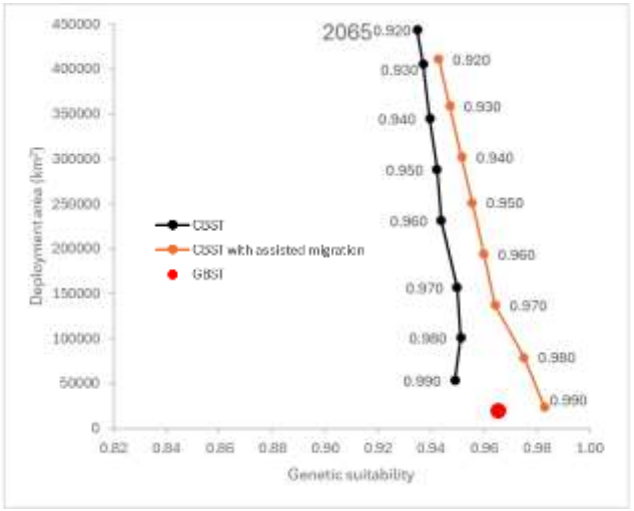


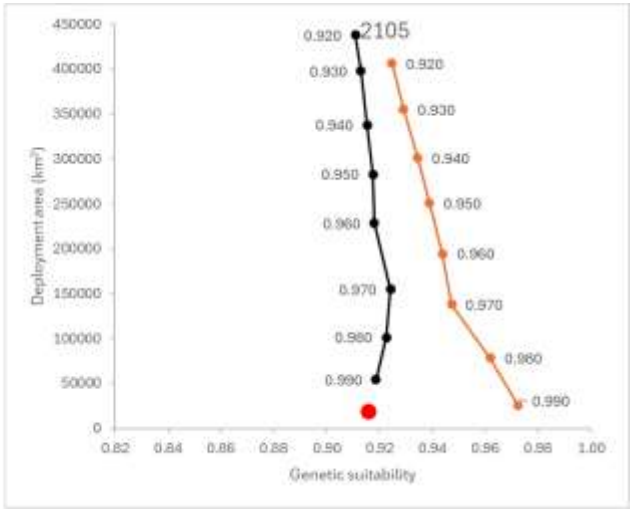
12. CBST evaluation



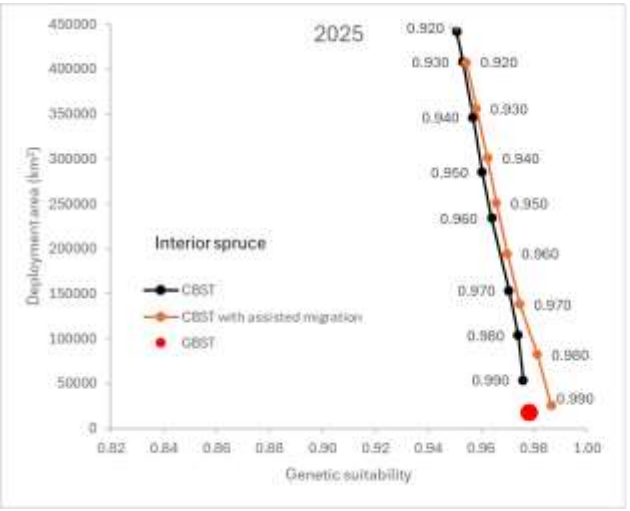
12. CBST evaluation

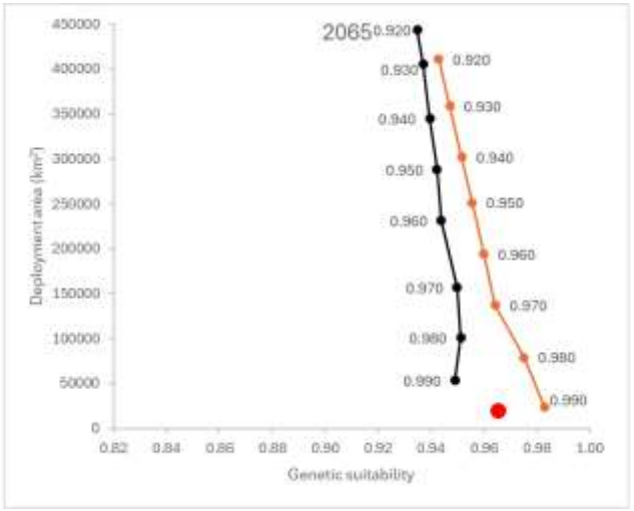


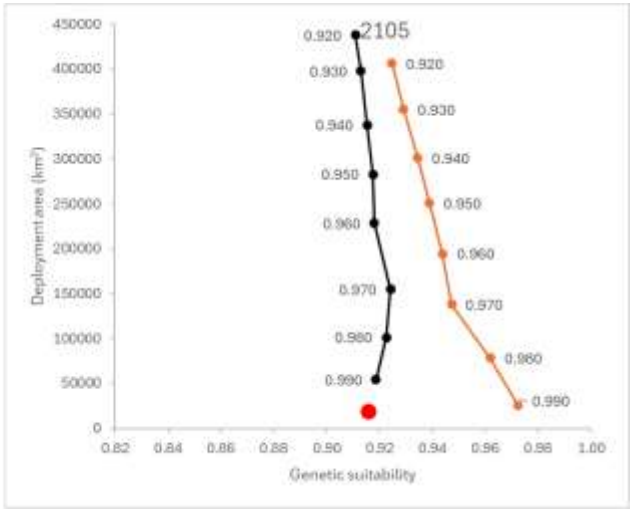


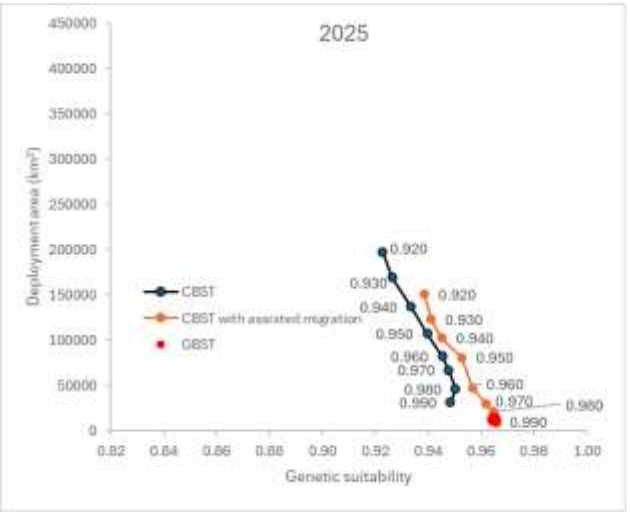


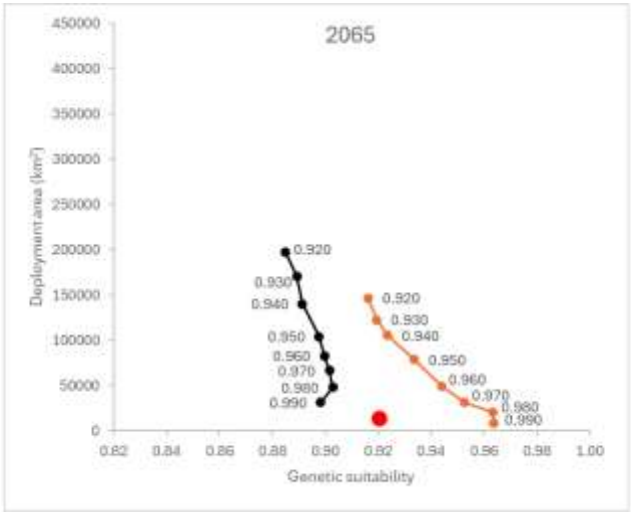
12. CBST evaluation

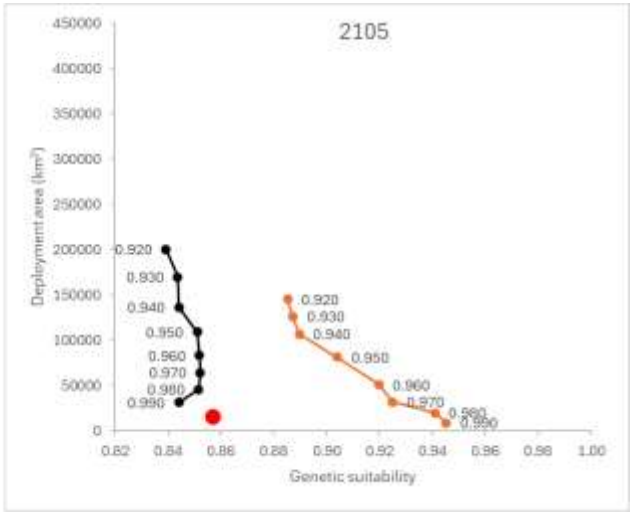






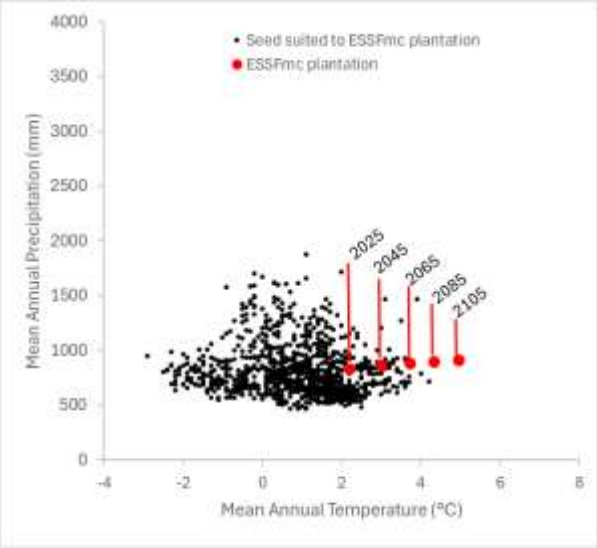






GS = 0.98

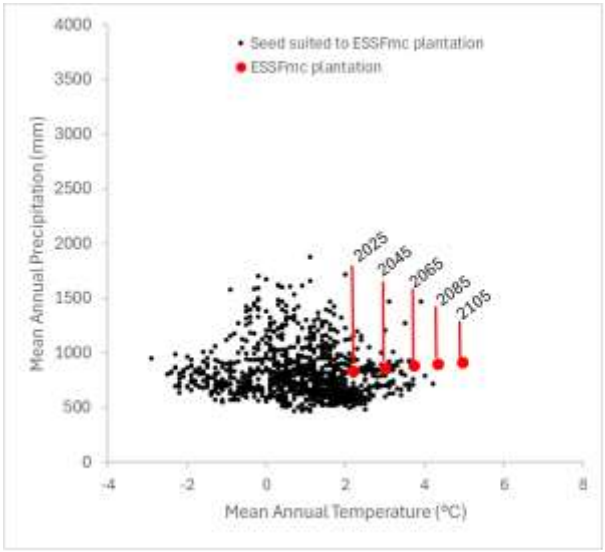
12. CBST evaluation



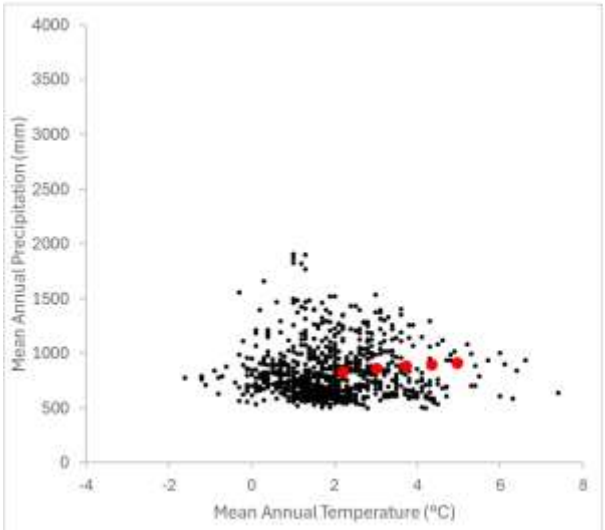
No AM

GS = 0.98

12. CBST evaluation



No AM

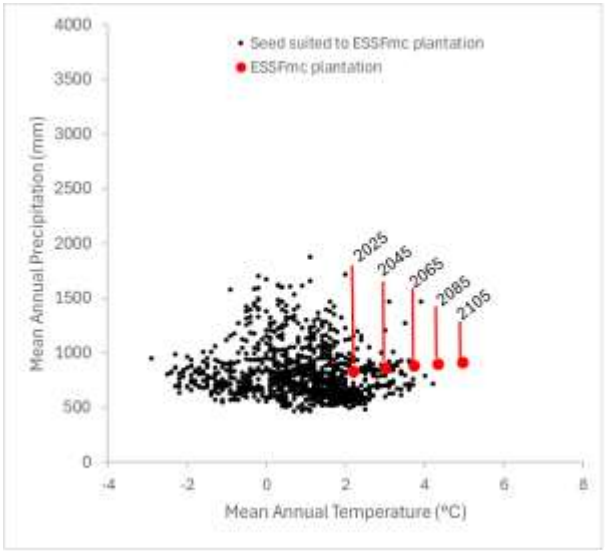


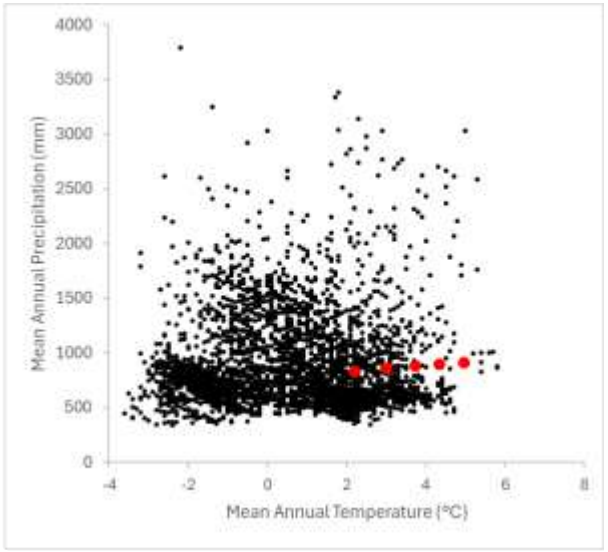
With AM

12. CBST evaluation

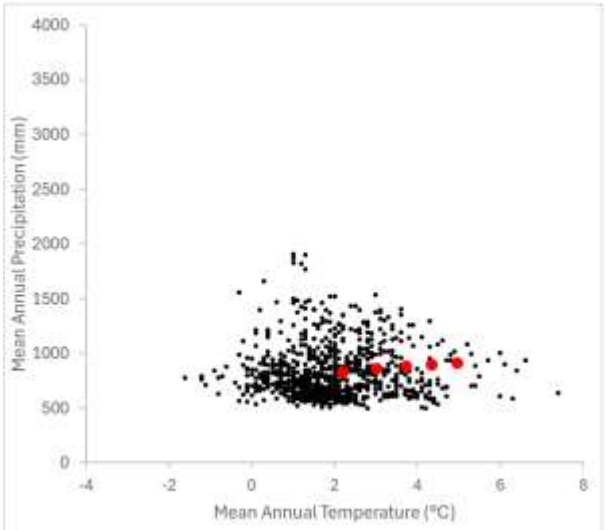
GS = 0.98

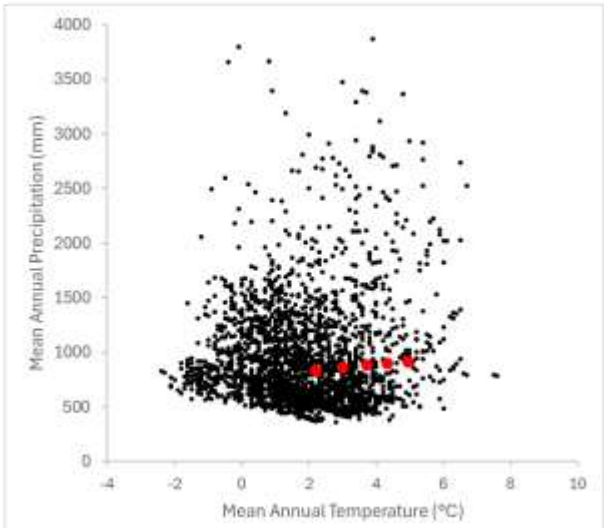
GS = 0.95





No AM





With AM

Climate Change Adaptation Research

2023 highlights

Extension

Date	Audience	Title/Workshop	Format
Jan	BC seed users and producers	extension update/ITAC	F2F presentation
Feb	USDA FS Silviculturalists	Understanding assisted migration	webinar presentation
March	Coastal Tree Improvement Committee	CBST and Coastal seed demand	webinar presentation
March	Forestry AM Tech Assistance Team	Implementing CBST in BC	webinar presentation
March	Society of American Foresters - National	CBST and AM	webinar presentation
March	Inland Empire Tree Improvement Coop	CBST - the BC experience	F2F presentation
April	Society of American Foresters - Alaska	Implementing CBST in BC	webinar presentation
May	Mast Reforestation Corp	AM and CC adaptation strategies	webinar presentation
May	Quebec foresters/ Carrefour Forêts workshop	CCISS and CBST in BC	F2F presentation (coauthor)
July	Researchers and genetics community	CFGA/CBST evaluation - Class A seed	field presentation
July	Researchers and genetics community	CFGA/AM field trials	AMAT field tour
July	Canadian Forest Genetics Association	Pinus brutia seed transfer	F2F presentation
Aug	Juergen Kreyling, Greifswald University	CBST and AM in BC	AMAT field tour
Aug	France - National Research Office	CBST and AM in BC	webinar presentation/discussion
Aug	Okanagan College students	Ecology class	webinar presentation
Aug	Jeffrey McDonnell - University of Saskatchewan	Reforestation and drought	tour/discussion
Sept	Kalamalka Senior Secondary students	Kalamalka Forestry Research	tour/discussion
Sept	Forest Nursery Associations (BC & PNW)	CBST and AM in BC	webinar presentation
Sept	Foresters	Southern Interior Silviculture Committee	AMAT field tour
Oct	Mosaic staff	CBST and AM in BC	webinar presentation
Oct	Nicola Valley Institute of Technology	Kalamalka Forestry Research	tour/discussion
Oct	BC Professional Agrologists Association	Kalamalka Forestry Research	tour/discussion
Oct	Vancouver Island University students	CBST and AM in BC	tour/discussion
Oct	Martin Gaywood, Scottish National Heritage	AM in BC	tour/discussion
Nov	BC MoF Researchers	BC MoF Researchers' Workshop	conference

Thanks!